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The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

VOL. 7 MAY, 1920 No. 3

COMMENTS

SEDIMENTATION OF VERY FINE SUSPENDED MATTER

When the study of water purification was taken up at the Lawrence Experiment Station of the Massachusetts State Board of Health more than thirty years ago, and when the chemical treatment of water by precipitants was studied, it was soon found that under some conditions material that theoretically ought to be precipitated and settle out, persistently remained in solution, or at least was so firmly held in the liquid that it did not separate. In all the years that have passed, this problem has remained one of the most troublesome ones in purification works. The amount of energy devoted to its solution by chemists has been very great. The practical results have been disappointingly small. Mr. Smith has taken up this subject in his paper in this number of the JOURNAL in a way that gives promise of adding to the practical knowledge of this obscure condition. It is to be hoped that he will be able to carry it to a successful termination.

There is a somewhat similar problem with smoke and furnace gases carrying finely divided solid particles. Great progress has been made in separating these solids in recent years It is to be hoped that corresponding progress may be soon reached in separating exceedingly fine particles from water.

In American water purification practice, one of our vices has been attempting to speed up processes that are necessarily slow.

Chemical reactions take time, and this is especially true when the quantities of materials that react are small and the temperatures low, and when the chemical reason for the reaction, so to speak, is only moderately strong.

In a coagulating basin that is too small, a reaction that will ultimately take place may have only partly taken place when the water leaves it for the filter. When this happens the water goes through the filter in an unstable condition, with the probability that the reaction will be completed in the pure water reservoir and in the mains, with the production of sludge deposits which are flushed forward at intervals, to the great annoyance of takers.

Waters containing lime, to the extent that they react with phenolphthalein, are likely to cause troublesome deposits of calcium carbonate. The author speaks of such a degree of alkalinity in treated water in some cases. The question may be raised as to whether it is not essential to ultimate success that such water should be recarbonated, or at least treated by a supplementary process that will remove this condition and make it so stable that calcium carbonate is incapable of separating from it.

ALLEN HAZEN.

THE IMPORTANCE OF COMPLETE INVESTIGATION WORK IN DETERMINING THE SAFETY OF WATER SUPPLIES FOR HUMAN CONSUMPTION

The importance of thorough investigation work in determining the safety of a given water supply for human consumption is now generally recognized by health authorities, but the significance to be placed on the various features involved in an investigation is still the subject of discussion. This disagreement, which largely concerns detail methods and their application, is to be expected, for the problem of determining the safety of a wide range of water supplies, or even the same source of supplies under varying conditions, is somewhat complex. There are certain fundamental principles, generally recognized by sanitary engineers, that can be applied and make it possible to give quite a definite opinion on the safety of a water supply. These principles recognize the fact that satisfactory investigation work on existing water supplies must include thorough field and analytical investigation before a safe opinion can be given. They further recognize that the individual undertaking the investigation must be properly trained to detect sanitary defects in the location, construction and operation of the

supply, to collect representative samples for analysis, to understand the principles involved in analytical work, to interpret analytical results properly with due consideration of the information obtained during the field survey, and finally to make recommendations for correcting existing defects or, if necessary, for the abandonment of unsatisfactory supplies.

In order to show the importance of the two fundamental parts of a water supply investigation, the field survey and the analytical results, a summary of six years' investigation work on existing water supplies by the Minnesota State Board of Health is given in tables 1 and 2. These investigations were made by representatives of the State Board of Health and each investigation included a

TABLE 1

Water supply investigations, 1912–1918

	WATER SUPPLIES INVESTIGATED	SATISFACTORY	UNSATISFACTORY
Number	1119	389	730
Per cent	100	34	66

thorough field survey and analytical examinations of the water. The supplies were not classified as safe unless their location, construction and operation were found to be satisfactory and the analytical results were shown to conform with the standards required for domestic water supplies in this State. It should be stated that the interpretation of analytical results was made with full knowledge of the field survey, which sometimes provided information that would alter an arbitrary interpretation of these results.

The investigations recorded in Table I represent both surface and underground water supplies from a variety of sources, including wells (dug, bored, drilled, driven), springs, lakes, rivers, creeks, etc.

Table 2 shows that the field survey was corroborated by the analytical results in 49 per cent of the cases; that the field survey was the only index of danger in 46 per cent; and the analytical results the only indication in 5 per cent. These results demonstrate the importance of thorough field survey work, for had the analytical results been accepted as the only index, 46 per cent of the unsatisfactory supplies would have been approved. It is also true that if the analytical work had been omitted, 5 per cent of the unsatisfactory supplies would have been overlooked.

It is evident from these results that both the field survey and

analytical results are necessary in order to determine the safety of an existing water supply for human consumption.

The field survey should give an accurate idea of the possibilities of present and future pollution. The analytical results should provide information on the sanitary condition of the water at the particular time the investigation is made and possibly some information of its past history. The field survey and analytical results combined should provide data for an opinion on the safety of the supply in its existing condition and afford information on which recommendations can be made for the correction of defects or for the abandonment of an unsafe supply.

TABLE 2

Unsatisfactory water supplies, 1912–1918

	UNSATISFACTORY WATER SUPPLIES	SHOWN UNSATISFACTORY BY		
		Field survey and analytical results	Field survey	Analytical results
Number............	730	354	338	38
Per cent	100	49	46	5

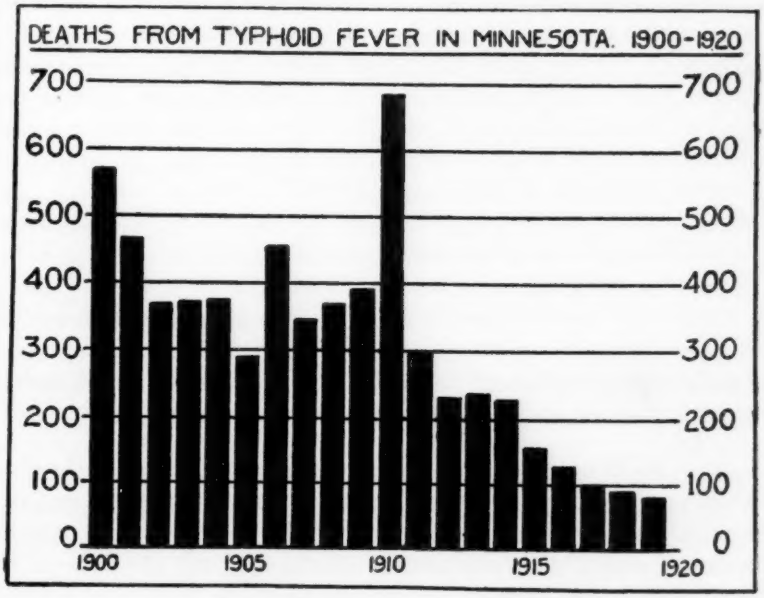
The purpose of this Comment is to emphasize the importance of complete investigation work by thoroughly trained individuals when the safety of an existing water supply is to be determined. The use of haphazard methods by unskilled individuals leads to erroneous opinions which may result in loss of life among the consumers of the water supply. H. A. WHITTAKER.

MINNESOTA'S TYPHOID FEVER RECORD

In connection with Mr. Whittaker's comments on the value of complete investigations of the safety of water supplies, attention is called to what the work of this sort by the Minnesota State Board of Health has accomplished. The data were recently given in *Journal of the Minnesota Public Health Association,* which states that in 1910 the State Board began a pure water supply campaign. The legislature appropriated $5000 for the work in 1911 and $7500 for the 1912 sanitary engineering work. The next year the appropriation was cut to $7000, at which figure it has since continued. In 1914 the Board's engineering and laboratory divisions were combined to make the present division of sanitation, which has charge of all work on water supply and sewerage systems. What it has

done in reducing typhoid fever, with the help of local authorities, is indicated by the accompanying diagram.

The average annual typhoid death rate in Minnesota from 1900 to 1910 inclusive was 428. During 1919 but 82 deaths were reported, a reduction of 246 from the yearly average from 1900 to 1910. There is an average of over twenty cases of typhoid for each death, making the reduction in the number of cases which would have occurred on that basis 6,920. This reduction has taken place in the face of a



EFFECT OF SANITARY WORK ON MINNESOTA TYPHOID FEVER RATE

25 per cent increase in population in the last twenty years. If it is assumed that a typhoid fever case costs an average of $150 for loss of time, doctors' and nurses' fees, hospital charges, medicines and other expenses, the improved sanitary condition of the state saved $1,038,000 and 350 lives last year. Such figures are conclusive proof of the value of that annual appropriation of $7000.

This is by no means all the story, however, for in every hundred typhoid fever cases there are three to five of the patients who become carriers, and continue to discharge virulent typhoid germs for months after they have recovered, sometimes for years. Unless they exercise great care, these persons are very dangerous members

of society. With a reduction of 7000 cases in 1919 as compared with the 1900–1910 period, there has been a corresponding reduction in the number of carriers, through the efficient work of the division of preventable disease.

Excellent as these records are, great as have been the strides forward in making water supplies safe, Mr. Whittaker's investigations show that there are many supplies which are unsafe. The work has reduced the hazards, but it has to be continuous and energetic to keep the hazards reduced. To bring about still more improvement means greater expenditures, for it is usually the easier problems to solve which are finished first, and as the field is covered the unit cost of accomplishing what is left generally rises. When the chart of what has been done is studied, when one reflects what suffering to the sick and anguish to their families have been saved for this small expenditure of $7000 annually, it is difficult to understand why all the money necessary to make the work more thorough and comprehensive cannot be found by the legislature of a state as wealthy as Minnesota.

John M. Goodell.

WILL CITIES EVER LEARN FROM THE EXPERIENCE OF OTHER CITIES HOW TO PROTECT THEIR PUBLIC WATER SUPPLIES?

Again an Illinois city has had the lesson brought home of the danger of permitting cross connections between the city water supplies and an industrial water supply of inferior quality. An outbreak including several hundred cases of diarrhea, about 130 cases of typhoid and fifteen or more deaths has been the price paid for this lesson recently at Bloomington.

Owing to the shortage of Bloomington city water (resulting mainly from having to supply the city of Normal with water while it was having trouble with its own supply) the Chicago & Alton railroad shops at Bloomington were requested to use as little city water as possible, which resulted in pumping a mixture of creek water and city sewage into its industrial supply. The mains carrying this filthy water were connected with the drinking water main carrying pure city water in one of the shops and the two supplies were separated by a single gate valve. A normal pressure of 60 pounds was maintained on the city supply and a pressure of from 120 to 180 pounds was maintained on the railroad supply, thus tending to cause the polluted water to be forced into the city pipes. After

work hours, the difference of pressure was even greater, for the city supply was shut off by means of the valve at the meter, and leaky fixtures permitted the pressure to drop to zero.

Following the outbreak, the connection between the two systems was at once suspected of having caused the trouble. The connection was, therefore, broken and the valve upon examination was found to be leaking badly. There is no question as to what caused the outbreak or where the infection entered, and now Bloomington, like many other cities, has learned a simple A. B. C. lesson but at frightful cost.

How long will it be until all communities as well as all industrial managements will realize the danger involved in permitting connections between safe and unsafe supplies of water? How long will it be until they realize that mechanical devices and the human element involved wherever a connection exists, can not be depended upon to properly safeguard the lives of those drinking the water? Let every waterworks official make it his business to see that his city removes at once any connection existing between the public supply and any other supply less pure! Do not wait until the horse is stolen before locking the stable door!

Paul Hansen.

RURAL WATER SUPPLIES

The serious effect of bad water supplies on the farms and in small villages upon the health of our cities has long been recognized, but only when a milk epidemic calls loudly to the public for more strict supervision of rural sanitation is any real action taken. We are too busy with our own affairs to think of farm wells. When some acquaintance dies from typhoid contracted during a vacation in the country, we usually decide to protest against the crimes committed against sanitation in the rural districts, and then we forget all about it. But there is one organization which has been steadily working for many years to make rural living conditions more hygienic. This is the United States Public Health Service, which is endeavoring, by cooperation with state and local authorities, to establish really efficient county health bureaus.

The work is done under one of those fifty-fifty systems of sharing expense which are now so often adopted by Congress in its state-aid legislation. In 1918 and again in 1919 Congress appropriated $150,000 for this work. In the latter year the Public Health Service asked for $500,000 for the work in 1920, but Congress reduced this

to $50,000. A similar request for $500,000 has been made for 1921. The nature of the work to be done is outlined by Dr. Lumsden elsewhere in this number of the JOURNAL. The work is not an experiment, but a demonstrated success, urgently requested by local associations ready to raise their share of the cooperative funds as soon as Congress makes it possible for the Public Health Service to act. If any member of our association thinks there is no need for such county health work and inclines to a belief that any danger of typhoid from rural districts is very remote, he should study the statistics in Bulletin 94 of the Public Health Service.

It has been said that this cooperative work is no untried experiment, but a demonstrated success. It is so much desired that the local authorities raise more than their share of the necessary funds. In the present fiscal year they have contributed more than five times as much to the cooperative funds as has Congress. They are not asking Congress to look after their health, but merely for expert assistance in getting efficient rural health service firmly established. Starting such work is far more difficult than carrying it on when well started, and it is for this special work that Congress is asked to furnish to Dr. Lumsden and his associates the funds necessary for extending these cooperative undertakings. It was the writer's privilege to become personally acquainted during the war period with some of the interesting and gratifying results of Dr. Lumsden's enthusiasm and ability, and on account of this personal knowledge he desires to call the attention of the Association to the desirability of larger federal appropriations for such work.

JOHN M. GOODELL.

SUPERVISION OF WATER PURIFICATION PLANTS IN TEXAS

One of the various duties of the State Board of Health of Texas is the supervision of the public or municipal water supplies of the state, especially those located in the smaller cities and towns. This particular obligation of the board is performed by the Bureau of Sanitary Engineering, a department of the Board of Health. The supervision consists in making sanitary surveys of the watersheds, looking after reservoir and well protection, locating foci of water-borne diseases and giving advice as to the proper operation of water purification and sterilization plants.

In conducting the work of the Bureau of Sanitary Engineering it was found that only a small percentage of the water works super-

intendents and filtration plant operators know anything regarding the quality of the water either before or after it left their plants. The men are not familiar with either chemical or bacteriological methods of analysis whereby they might be able to make such tests as would establish the safety or potability of the water. They are usually engineers or mechanics and concern themselves principally with the mechanical and operation features of the plant; the purity of the water and even the economical details of operation are, too often, neglected.

Several plans of helping such men in charge of water purification plants, and water works men in general, were considered. Conferences with members of the faculty of the University of Texas were arranged and it was decided to formulate a course of instruction and present the work at the University of Texas. The schedule of studies as outlined and carried out embraced the rudimentary principles of the chemical and bacteriological analysis of water, lectures on the scientific operation of filtration and sterilization plants, geology of underground water supplies, protection of watersheds, key rate determination in fixing fire insurance rates, and the legal responsibility of water companies. Illustrated lectures on the various subjects were also given. Conferences were held at which the problems of the individual attendants at the course were discussed in detail.

No books on chemical and bacteriological analysis, written in plain, everyday language which could easily be understood by the class of men we intended to instruct, were obtainable, so a pamphlet was written covering these subjects. Technical formulae and phraseology were omitted wherever it was possible to do so. This booklet also explains in detail the treatment required by various types of water, and the operation of water filtration and sterilization plants.

The results obtained surpass the expectations of both the University authorities and the Bureau of Sanitary Engineering. The men showed a most commendable determination to learn and master all of the work offered. We feel that these men, who, previous to their attendance at this school, knew very little or nothing about methods of analysis or chemical control of filtration and sterilization plants, are now able to make the tests and analytical determinations required in the routine operation of small plants. Personal contact and interchange of ideas with men in similar lines of work has a broadening influence which can be gained in no other way.

Plans have already been formulated so that the course will be offered again next year on a larger and more elaborate scale. It is possible that the length of the term will also be extended from two to four weeks. In order to more permanently establish this school of instruction as a yearly institution at the University, the Texas Water Works Association was organized. This society was formed with more than sixty charter members on its rolls and the list is continuing to grow rapidly. In order to promote the original purpose of the organization, the founders of the society broadened the eligibility qualifications so that all water works men, no matter in what capacity employed, may be admitted as active members. Among other innovations, the association has already considered the advisability of recommending the enactment of a state law providing for the licensing of all water purification plant operators and other persons responsible for the quality of water served to the public.

LEWIS O. BERNHAGEN.

A BRAVE DEED

The brave facing of great danger is reported unexpectedly and for strange reasons in times of peace. On January 23 such bravery was shown by a foreman of the Terre Haute Water Works Company and a switchman in the Terre Haute plant of the American Car & Foundry Company. Frank M. Johnson, the foreman, and another employee of the water company, named Shepherd, visited a meter vault at the entrance to the industrial plant to make the regular monthly meter reading. The meter vault is a vault 12 feet long, $4\frac{1}{2}$ feet wide and $4\frac{1}{2}$ feet deep, with dirt bottom, brick walls and concrete roof covered with about 2 feet of earth. It is entered at one end through a manhole only 20 inches in diameter, with a perforated lid. The vault is built in sandy soil.

Shepherd entered the vault, but before he had been there five minutes Johnson, on looking down, saw that he had become unconscious and was lying with his face against the side of the vault. Johnson called for help and two men ran up. Johnson had meanwhile leaped into the vault, and had succeeded in lifting Shepherd to a little board platform under the manhole by the time the men reached the spot. With their help and that of the switchman above mentioned, Daniel Boyer, who came up about the same time, Shepherd was dragged through the narrow manhole, and recovered later.

By this time Johnson in turn had been overcome and was lying at the bottom of the vault. Although Boyer saw that two men had been rendered unconscious, possibly fatally injured, he clambered into the vault, fastened the end of a chain about Johnson's chest so he could be lifted up, and climbed out. The chain became unhooked as Johnson was being lifted out, and Boyer entered the vault again, this time with a rope which he fastened under Johnson's arms. He nearly lost consciousness before he could get out of the vault. Johnson was removed in an unconscious condition to a hospital and for some time was not expected to recover.

These men took the hazard of life and death as voluntarily as can be done. Johnson, a man of 39 years, with a family, could not let a fellow workman die in a vault evidently filled with some poisonous gas. Gas had been detected there before, which was the reason for placing a perforated cover on the manhole, but it had never caused trouble. Johnson knew the danger, however, when, without any certainty that assistance would come in time, he went after Shepherd. That he is living today is great good fortune, for all the odds were against him. The pluck with which Boyer, a man 60 years old, entered the deathly vault twice after Johnson, and the nerve with which he kept his head even when almost overcome, again go to prove that it is not only brash youth that is ready to face the great adventure bravely and efficiently when the call of duty comes. And let us all make sure, if we can, that our men are not called upon to enter such dangerous places in the routine work.

JOHN M. GOODELL.

THE EXPERIENCE OF THE SPRING VALLEY WATER COMPANY IN RESTRICTING THE WASTE OF WATER IN SAN FRANCISCO[1]

By G. A. Elliott[2]

The conservation of water in San Francisco is far more important than it is in any other city of similar size in the United States. The city is located at the extreme tip of a peninsula over 30 miles long, upon which a limited amount of water can be developed. The rainfall is limited, averaging a fraction over 22 inches a year. Due to its geographical isolation, its hilly topography and its scant rainfall, the problem of water supply is not only physically difficult, but is also very costly. An increase in the present developed supply involves the construction of about 60 miles of conduit. On two occasions in the past ten years, it has been expedient to reduce the waste of water to a minimum, the first time following the dry season of 1912–13, and the second time following the year of the Panama-Pacific Exposition.

In 1913 there were 63,016 services in actual use, of which 43,444 domestic supply services were on a flat-rate basis, and 19,572 devoted to business, industrial and hotel uses were metered. The water rate ordinance passed annually by the legislative board of the city prohibited metering domestic consumers except in extreme cases of wilful waste. Under these conditions, practically the only method that could be used for the restriction of waste was house to house inspection for leaks. This plan was followed out, and considering the fact that only out and out leaks could be controlled and not thoughtless or deliberate waste in the use of water, the results were surprisingly good.

Beginning in April and covering a period of eight months, a party of ten men equipped with aquaphones, made an examination of all the unmetered services in the system. The inspection was carried out between midnight and 5.00 a.m., the assumption being that any

[1] Discussions of this paper are requested and should be sent to the Editor.

[2] Chief Engineer, Spring Valley Water Company, San Francisco, Calif.

water flowing at that time was due to leaky plumbing. Following the night inspection, six day inspectors were used in visiting all premises which had been reported as leaking. These men definitely located the leaks and notified the owner to have repairs made. Two weeks after the day inspection, a second night examination was made and, if necessary, a second notice was served on the consumer. As a general rule, the second notice was not required, as repairs were made after the first warning. On the night work, each man examined 14 services an hour on an average. The day men, who were required to inspect all of the fixtures in a building and point out the leaks to the consumer, covered six houses per hour on the average.

A total of 43,444 premises inspected revealed that 25,419, or 58.6 per cent, had leaky plumbing. Up to the end of the year, when work was discontinued, repairs had been made in 23,372 cases, amounting to 92 per cent of the total number of leaks.

The result of this work on the consumption is shown in figure 1. In 1913 although the work was not commenced until April and the first inspection accompanied by notices to consumers was not completed until September, it was estimated that at least 1,200,000 gallons daily had been conserved. In 1914 the consumption was at least 3,000,000 gallons daily, or 8 per cent, below what it would have been if allowed to proceed unchecked. In 1915 the influence of the Panama-Pacific Exposition artificially increased the use to such proportions that the further effect of the inspection could not be determined.

In 1916, following the Exposition year, the daily consumption had reached a point where it was necessary to either increase the development or still further restrict the waste of water. The effect of the war on prices of water works materials was beginning to be felt. After careful consideration by all parties interested, it was decided to conserve the existing supply through the installation of meters on about one-half of the flat-rate services. The installation of meters on the remaining services was to be made at a later date, depending upon the effect of the first batch upon the consumption and the fixing of a meter rate for the sale of water. Work was commenced on August 1, 1916, and continuously prosecuted until March 30, 1917, when about 25,000 meters had been set.

Just a year later, anticipating the establishment of a temporary meter rate (which was finally fixed in September, 1918), the metering of the remaining 25,000 flat-rate services was commenced and car-

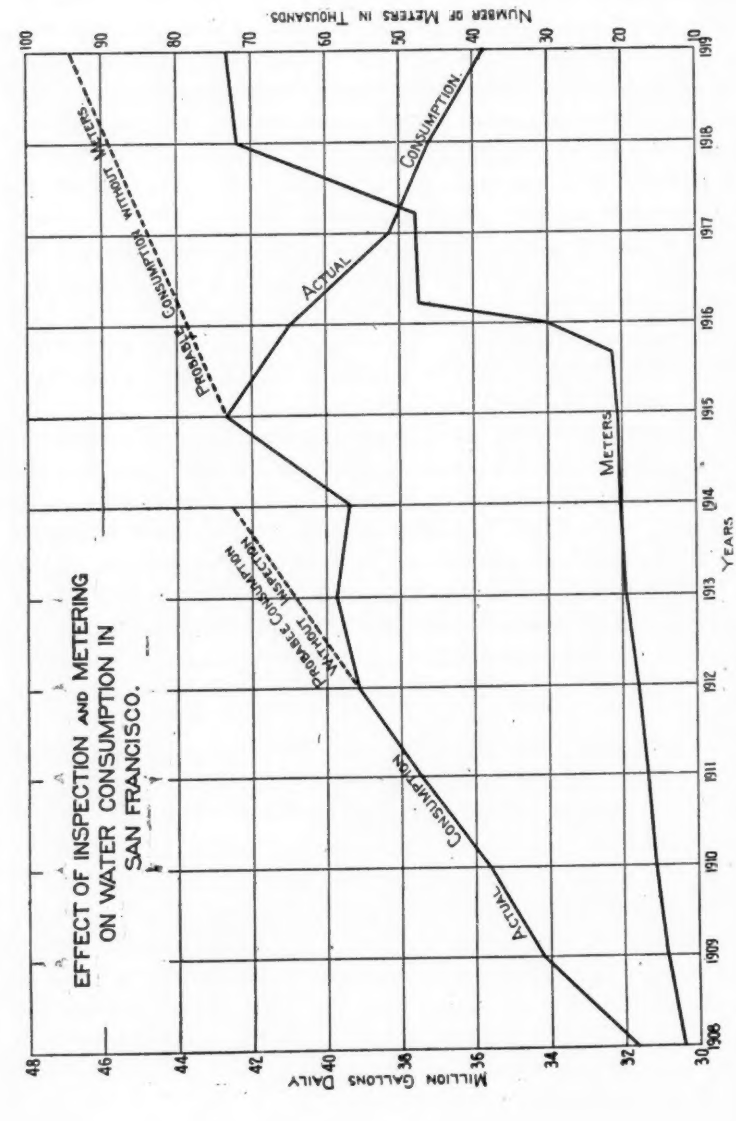


Fig. 1.—Results of Water Waste Preventative Measures in San Francisco

ried on until in August, 1918, San Francisco was 100 per cent metered. The size and number of crews used varied, but in general it was found that the proper proportion of men was one-third pipe fitters and two-thirds common labor. The average number of meters set per crew man per day was 4.70.[3] In this connection it must be remembered that many of the services had been in use for over forty years and that the location records had practically all been destroyed in the fire of 1906. In fact the wireless pipe locator was in constant use and saved a great deal of useless excavation.

The result of the meter installation on the consumption is shown graphically in figure 1. The outstanding feature of the diagram is the fact that the decrease in consumption has gone on over a four-year period, the estimated reduction for the year 1919 amounting to 12,000,000 gallons daily or 25 per cent of the probable unrestricted consumption. The rather long drawn out period of continually decreasing consumption is readily explained by the history of the case. Referring again to the diagram, it will be noticed that the period of setting the first batch of meters covered 1916 and 1917. The effective reduction in consumption up to the end of 1917 was due almost entirely to psychological reasons, as there was not a practical meter rate in effect during this time. While it is true that the waste clause of the old water-rate ordinance was in effect (providing that if the amount of water used in a month through a service exceeds by 50 per cent the number of cubic feet which at meter rates amounts to the consumer's flat rate bill, the Water Company may charge "at regular meter rates") the margin between necessary use and wasteful use as defined above was so great as to practically prohibit any effective monetary penalty for the latter.

In September, 1918, a temporary meter rate in the form recommended by the New England Water Works Association was authorized by the State Railroad Commission pending a final rate-fixing by that tribunal. The application of this rate to all consumers, together with the metering of the remaining open services, accounts for the continuation of the decrease in consumption up to the end of 1919. It is not likely that this decrease will continue beyond this year. Preliminary census figures indicate a population of 600,000 for San Francisco. On this basis the use of water in 1919 from the Company's system amounted to 60 gallons per person per day. The

[3] Cost details are given in *Engineering News-Record,* May 9, 1918.

unaccounted-for water, (i.e., water used for fire purposes, street sprinkling, reservoir evaporation, leakage, etc.) for the last year was less than 22 per cent of the total amount withdrawn from the sources of supply.

The methods used and the physical and hydraulic facts attendant upon the wholesale installation of meters on an unmetered system, while of interest to the engineer or operator, are probably not as important as the effect of the new policy upon the public. This is true of both public utilities and municipally owned water works. While it is not difficult to convince the individual of the fairness of meters in the abstract as a means of properly allocating the water charges, it is an almost insurmountable task to convince the same man that justice is being done if his own bill is thereby increased. It was recognized that individual contact with all consumers was impossible, and that in the main they could only be addressed as a body. It was determined to conduct a campaign of education through the medium of the daily papers and the use of pamphlets, supplemented by talks to various civic associations.

Coupled with the advertising campaign a liberal policy in the matter of adjustments, especially on the first two monthly water bills following the inauguration of the meter charges, and the free service of the Company's inspection department in locating leaks in either house piping or fixtures, did much to tide over the period of changing from flat to meter rates. Full advantage was taken of the fact that the monthly bill collectors came in personal touch with the consumer in their house-to-house visits. All of these men were thoroughly drilled in the fundamentals of rate fixing and particularly in regard to the existing rate. Consumer's questions brought up new points for explanation each day and periodical gatherings of the collectors were held, at which the necessary information was given to them, to be in turn passed to the householder. This personal touch was of great value, as most of the collectors were well known to the customers through having covered the same route for years.

Still another important factor which was effective in securing the good will of the consumer was the changing of the existing meter to one of smaller size when the consumption permitted this procedure to be followed. The form of the rate bill was such that each consumer's monthly bill was made up of two parts: a "service charge" based on the size of the meter installed, varying from 65 cents per month for a $\frac{5}{8}$-inch meter to \$40 a month for an 8-inch meter, plus a

charge for each 100 cubic feet of water used through the meter. The following somewhat arbitrary amounts were fixed as being the average monthly quantities to be used through meters of various sizes.

METER SIZE	MONTHLY QUANTITY	MONTHLY SERVICE CHARGE
inches	*gallons*	
$\frac{5}{8}$	4,000	$0.65
$\frac{3}{4}$	7,000	1.00
1	12,000	1.50
$1\frac{1}{2}$	24,000	2.50
2	40,000	4.50
3	80,000	8.00
4	122,000	12.50
6	245,000	25.00
8	410,000	40.00

For instance, if it was noted that a consumer's 1-inch meter consistently read under 4000 gallons per month, a $\frac{5}{8}$-inch meter would be set by the Company, thereby saving the user the difference in the service charge. In some instances it was possible to replace 2-inch meters with those of the smallest size, thereby effecting a considerable saving to the customer. Inasmuch as the ordinary water user is not sufficiently familiar with meter capacities to determine these facts for himself, this voluntary action of the Company resulted in a better mutual feeling.

The advertising feature was of such importance that a department was created for this purpose alone and placed under the direction of Edward F. O'Day, who had a varied experience as a newspaper and magazine writer. A series of advertisements running into the hundreds in number and extending over a period of eight months, was published in all of the daily papers. Naturally that part of the rate bill having to do with the "Service Charge" received the principal attention. Many of the consumers were under the impression that they were being charged a monthly rental for the meters; others that a certain amount of water should be delivered for the payment of this charge. The advertisements not only cleared up in the minds of many of the rate payers the method of allocating the components of the water rates, but drew forth many letters of inquiry. These letters were answered individually. It may be of interest to quote here a few typical replies.

A. Water is now sold entirely according to measured delivery. Formerly residential consumers paid a fixed monthly rate irrespective of the quantity drawn. The plan was responsible for many inequalities. There was practically no restriction on wasteful or excessive use. On the other hand, careful consumers had no opportunity to profit by their economy.

Under the meter schedule these matters automatically adjusted themselves, each user paying for actual delivery. Bills are large or small according to demand and condition of plumbing.

B. The service charge on water bills is a legitimate item duly passed on by the rate-fixing bodies, and represents not an additional charge but a division of the total cost.

The present schedule gives one value for the water in the mains to all, plus a service charge to the *individual*. As it costs as much to *deliver* water to a user of 100 cubic feet as to a user of 1000 cubic feet, the equity of this arrangement will be apparent.

C. It is unfortunate, but not conclusive of error or wrong, that the bills referred to by you are slightly higher than they were before. The opposite result will be produced on fully 50 per cent of all bills issued. With certain modifications the general effect will be that small users, to serve whom requires as heavy an investment as to serve large users, will pay somewhat more, the other class somewhat less.

D. The "service charge" item, which now appears on all water bills, represents that part of the total charge which covers the cost of installation, upkeep and administration.

The "delivery charge," on the other hand, represents the cost of accumulating the water and bringing it to the point of distribution. A base rate of 24 cents a hundred to all consumers has been set for the water in the mains; to this is added the service charge, which obviously remains the same whether the demand is large or small.

Formerly two rates were in effect: (1) flat rate for residential properties, based on area and equipment entirely, and not at all on use and occupancy; and (2) meter schedule for all other supplies, the base rate being 28¾ cents a hundred cubic feet.

The flat rate was wrong because there was no relation between value given and revenue received. Some flat rate consumers paid too much, others too little; moreover, the consumer had no incentive either to exercise care in the use of water or to keep his plumbing in sound condition.

The old meter rate was wrong; first, because the minimum charge of $1.80 a month made no allowance for the consumer who used 500 cubic feet of water a month or less, and secondly, because the sliding scale used was not in good balance, the load being placed on the intermediate user to the advantage of the very heavy consumer.

The present schedule, which is the result of much study and deliberation on the part of the rate experts and representatives of the City of San Francisco, the State Railroad Commission and the Spring Valley Water Company, while tentative, approximates the ideal rate for both consumer and company, is simple in application and logical in operation, the amount of the charge depending entirely on the quantity of water drawn, and not on any arbitrary factor, such as the size of the premises, etc.

The advertisements were so composed and arranged that while each was complete in itself, the entire series told a connected story. They began with the question of water supply in general, followed by a description of the local water supply, pointing out the ways and means used to supply San Francisco and touching on those features which involved special difficulties and unusual cost. The fundamen-

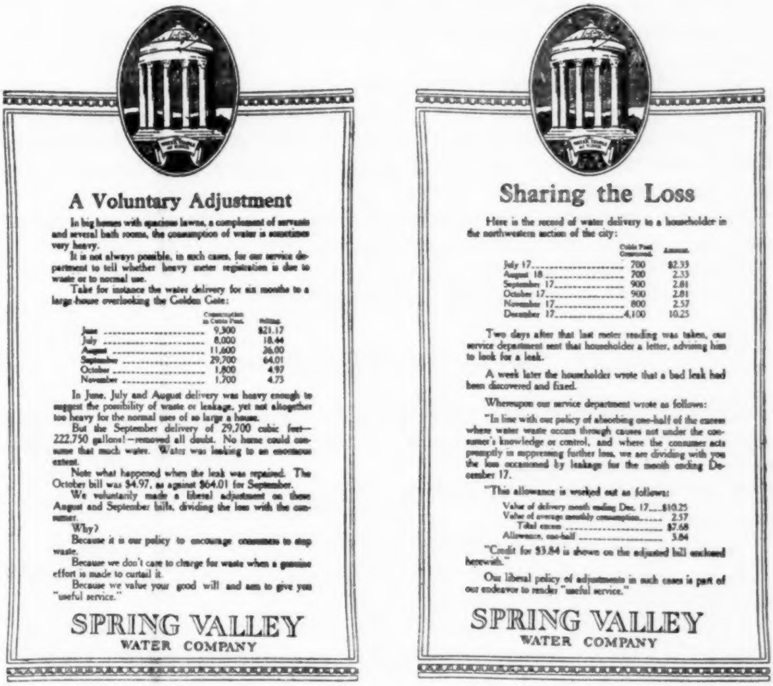


Fig. 2—Much Reduced Copies of Two Advertisements

tals of rate fixing, discussing what must be considered in setting a price for the sale of water and giving the reasons for these considerations, were taken up next. This naturally brought the series to the subject of the various kinds of water rates and the meter rate in particular. Two samples of the advertisements are given in figure 2, and the text of a few more is reproduced here.

Equitable Billing

There are two items in your water bill—a charge for water, and a charge for the actual cost of service.

The charge for water depends on the number of cubic feet you use. The charge for service is the same every month.

If you are the average householder, you pay for water at the rate of 24 cents a hundred cubic feet (750 gallons). For the cost of service you pay 65 cents a month.

The charge for water is based on what it costs us to collect the water, impound it, keep it pure, convey it to San Francisco, and "lay it down" in front of your house.

The service charge is what it actually costs to connect your service pipe and meter, keep them in repair, read your meter, keep your account and collect your bill.

Your bill has been itemized this way ever since the complete metering of the city enabled us to compute exactly how much water each household consumes.

This form of bill is fairer than the old, and has advantages of which you should avail yourself. It has no advantage to us except the equitable distribution of charges.

Compare your water bills from month to month. If the charge for water varies a good deal, you may be wasting water, or there may be a leak.

The old style bill was meant to be fair, but in most cases it was not.

Your present bill is businesslike, logical and just.

The Old Way and the New

Under the old way of charging, with the service charge included in the lump sum of the bill, the base rate for water was 28.75 cents per hundred cubic feet as against 24 cents at present.

If you were a commercial consumer and paid meter rates, you never paid less than $1.80 a month.

That was the minimum meter bill, and it included a service charge.

If you were a residential consumer, you paid according to size of house and lawn, and number of water fixtures.

The service charge was supposed to be included in your bill. Sometimes it wasn't, if your premises were small. Sometimes you were charged too much for service.

With the whole city metered, and a separate service charge, these inequalities have been ironed out.

The bills of some 40,000 of our 70,000 consumers have been reduced.

Surely a method of billing which reduces 64 per cent of the bills is an improvement.

If we went back to the old bill, without the separate service charge, nearly two-thirds of our consumers would pay larger bills.

Paying for Service

If you bought water at a city reservoir, paid cash for it, and carried it home —as you sometimes carry a purchase from the store—your water bill would be smaller.

The price you paid would depend on what it cost us to bring the water to San Francisco and sell it over the counter. Expenses which every consumer pays under present conditions would be eliminated. There would be no service pipes and meters to maintain, no meter reading, bookkeeping or bill collecting.

But you can't shop for water, and you wouldn't if you could. You want it to flow at good pressure the moment you turn on the faucet. You demand service.

When you have a purchase sent home you pay for service. Sometimes there is a direct delivery charge—usually the charge is absorbed in the price of the goods.

For water delivery you have to pay, too—but you pay directly, the charge being distinct from the rest of the bill. Why? Because the cost of service varies and cannot equitably be prorated. Each consumer is charged what it costs us to serve him—no more, no less.

There is a service charge hidden in almost every bill you pay.

It is not hidden, it is where you can see it, in your water bill.

You Must Have Service

A consumer writes us this note:

"I don't understand the service charge of 65 cents. I never ordered service. All I want is water."

This consumer does not stop to think that the water business is like any other business.

Take the coal business.

All you want from your coalman is coal, but you expect him to haul it to your sidewalk and dump it in your cellar.

All you want from us is water, but you expect us to supply it in a way that suits your convenience.

You not only pay the coalman for coal, but you help to pay the wages of his truck driver, bookkeeper and bill collector. That's service charge in the coal business.

You not only pay us for water, but you pay for the maintenance and repair of your service pipe and meter, for meter reading, billing and collecting. That's service charge in the water business.

The coalman includes his service charge in the price per ton.

The water schedule separates service charge from the price per cubic foot.

In both cases you get service and must pay for it.

A ton of coal dumped in the middle of the street wouldn't do you much good. If we didn't give you service how would the water get into your house?

Not a Meter Rental

There is an idea in some quarters that "service charge" is the same as "meter rental."

Insofar as the service charge for water in this city is concerned, this is a mistake.

You pay no rental for your water meter.

The service charge is a cost charge, not a rental charge. It represents the cost of serving you individually with water.

We have always charged for service, even before meters were installed throughout the city.

In theory every consumer was supposed to pay his share of the cost of service. In practice this was not the case.

Such was the inequality of the old way of billing that some paid nothing for service, some paid only a fraction of the cost, and others paid too much.

At present the service charge is figured separately from the water charge, and every consumer pays what his individual service costs.

The charge depends on the size of the meter.

But nobody who understands the service charge will mistake it for a meter rental.

It Can't Be Abolished

We have heard the remark that the service charge for water should be abolished.

People who say that don't understand the situation.

You can't abolish the service charge any more than you can eliminate from the water business the expenses which the service charge represents.

It's an unavoidable charge, and consumers have always paid it, and always will.

But sometimes they have paid it on a basis that was not entirely fair to them individually.

The service charge is inseparable from the water business. Of course it can be hidden—absorbed—combined with the rest of the bill. You can stop calling it the service charge.

There will be this difference—the water rate will be higher and not so equitable.

The old base rate was 28.75 cents, which included the cost of service. It is now 24 cents per 100 cubic feet, and you pay for service as a separate item.

This is fairer to you, but the results to us are almost the same.

The change was made in the interest of the consumers, not to benefit us.

The Case of John Smith

John Smith has a tiny cottage. He uses very little water—about 100 cubic feet a month.

When flat rates were in effect, his bill was 25 cents a month.

Under the meter rates he pays 24 cents for water plus 65 cents service charge —89 cents a month.

John Smith used to pay for water only—we served him for nothing.

There were about 2,000 consumers in San Francisco who paid from 25 to 75 cents a month under the old flat rates. We served them at a loss.

On the other hand some consumers paid more than they should. They paid enough more to make up our loss on those 2,000.

Making a separate service charge has corrected all that inequality.

Of course, John Smith does not like to pay 89 cents a month instead of 25. But we assume that he's a fair-minded man, and doesn't expect to get water at a price so much below its cost that others must make up the loss.

Each consumer now pays his fair share. One does not carry another's burden.

Read Your Water Meter

"The lowly meter is regarded by some householders with distrust, but is in reality a faithful servant."

The speaker who made this statement at a Los Angeles convention of public utility officials, urged a campaign to educate consumers to read their meters and "thus obviate heated discussions between consumers and companies over the question of whether meter readings are correct."

The Spring Valley Water Company has pursued a consistent policy of coöperation with consumers who desired to inform themselves about the water meter, with the result that complaints on the subject are extremely rare.

Domestic consumers have paid meter bills a little more than a year. At first some were inclined to regard the meter with distrust. But at present the accuracy of the measuring machine is generally understood. The reason is that we have taken pains to explain the meter, to meet complaints courteously and to keep in mind that utility service should mean "useful service."

We have shown thousands of consumers that leaks were responsible for abnormal water bills, not the inaccuracy of the meter.

We have urged householders and other consumers to read their meters, and thus keep track of water consumption, pointing out that where the meter is read every few days, leakage is discovered and may be checked before it affects the bill. The meter is a great leak detector.

During the past six months we have distributed more than ten thousand copies of a folder entitled "A Check on Waste." This folder explains the meter dial and gives simple directions how to read it. There is a ruled space for a record of meter readings.

The consumer who reads his meter is in a position to verify his water bill. He does not think of the meter with distrust. He has no occasion to enter into "heated discussions" over the correctness of meter readings. He is making his water meter serve him to the fullest extent.

Write or call for a copy of "A Check on Waste," and learn to read your meter.

A Case of Insomnia

Running water as a remedy for insomnia!

This was the most curious case in our experience.

It happened in an apartment house. The water bill was abnormally large. So a thorough inspection was made.

The heavy waste of water was traced to a tenant who kept the faucet flowing full head in the bath tub every night. He explained that he had to do this because the sound of running water was the only thing that would make him sleep! Perhaps he was a retired sailor.

As the enormous waste of water meant no money out of his pocket, he slept soundly every night. If the landlord had insomnia, he should worry!

But when the landlord got through with him, he decided to seek some less expensive cure for sleeplessness.

A good deal of water is lost through wanton waste of this sort, but the really serious losses are caused by leaking fixtures.

The commonest cause of heavy loss is toilet leakage. There's a reason for this. A leaking faucet is a nuisance, and you generally lose no time in getting a new washer. But a toilet may leak badly without your being aware of it.

If your bill takes a sudden jump, and you know you haven't used more water than usual, notify our service department.

Our inspectors are making constant warfare on leaks. Every day they are helping consumers to reduce their bills. Maybe they can help you.

Let our service department show you that with us utility service means "useful service."

"Fairly Careful"

When the consumer who is "fairly careful" gets his water bill, he says: "This bill seems to be about right."

And yet, owing to leakage, his bill may be growing a little larger every month. The chances are, he doesn't wake up until it is twice as large as it should be.

Take the case of this shopkeeper:

	Cubic feet consumed	*Water bill*
March	4,000	$10.39
April	4,100	10.60
May	6,300	15.22
June	7,700	18.16
July	8,100	19.00
August	10,000	22.99
September	4,500	11.44
October	4,200	10.81

This consumer had use for the same amount of water, more or less, during all these eight months.

In May his bill went up, but being "fairly careful," he thought it was "about right."

But when in August it was more than double what it used to be, he realized that something was wrong.

While he was thinking of making a complaint, our service department made a voluntary investigation and found a blind leak.

As soon as it was repaired, the bills were normal again.

If this consumer had kept close tab on his meter readings—if he had profited by our folder, "A Check on Waste"—he would have found that leak before it got bad.

To save money nowadays you have to be *extremely careful* about all your bills, including your water bill.

It is now somewhat over a year since the meter rate was first applied, and the policy of frankly placing before the consumers the reasons for meter rates has fully justified itself through the results obtained. Opposition to and criticism of the meter rate has practically disappeared. Consumers have been encouraged to read their own meters and thus discover unusual registration, usually due to leaks. It can safely be said that at the present time the majority of the consumers are better satisfied with the meter rate than they were with the flat rate.

THE REMOVAL OF CLAY AND SILICA FROM WATER[1]

By Otto M. Smith[2]

Silica is found in natural waters in two forms, the one insoluble and the other soluble. In the latter it is usually known as silicic acid and is reported as SiO_2 in the ordinary water analyses. In solution it occurs in a colloidal form or in combination with the basic elements. Its presence in water used for steam purposes has always been considered as detrimental and conducive to the formation of a hard flinty scale. Silicic acid is said to be responsible for many boiler disturbances. When the acid is distilled with water solutions of nitrates and chlorides, nitric and hydrochloric acid are liberated.

Turbidity in water is generally caused by the suspensions of very finely divided mineral matter, mainly clay. Clay may be defined as a mixture of minerals of which the most representative members are the silicates of aluminum, iron, and the alkalies, and the alkaline earths and organic substances. The hydrated aluminum silicate or kaolin (Al_2O_3, $2SiO_2$, $2H_2O$) is the most abundant compound.

There are many instances in the literature emphasing the difficulties of clarifying water containing finely dispersed clay particles. Fuller[3] and Ellms[4] found that at times there occurred a turbidity in the Ohio River that was difficult to coagulate and required an abnormal consumption of alum. Black and Veatch[5] and Catlett[6] show the difficulties in the treatment of such water.

Properties of colloids. As silicic acid and a clay suspension are considered to be present in water in a colloidal form, a brief discussion of the general properties of colloids will be desirable. Burton defines a colloid solution as

[1] Read before the Illinois Section, March 25, 1919. Discussion of this paper is requested, and should be sent to the Editor.

[2] Chemist, Procter & Gamble Company, Ivorydale, Ohio.

[3] "Water Purification at Louisville, Ky."

[4] *Engineering Record*, 51, 552 (1905).

[5] *Engineering Record*, 72, 292.

[6] *Engineering Record*, 73, 741.

A suspension, in a liquid medium, of fine particles which may be graded down from those of microscopic to those of molecular dimensions; the one property common to all such solutions is that the suspended matter will remain almost indefinitely in suspension in the liquid, generally in spite of rather wide variations in temperature and pressure; the natural tendency to settle, due to the attraction of gravitation, is overbalanced by some other force tending to keep the small masses in suspension.

It is possible to show that there is a continuous gradation in the size of particles from those invisible to those of microscopic dimensions and this leads to the belief that there is a gradation in size from the smallest of these to that of molecules. Small microscopic objects have a continuous movement known as the Brownian movement. If to a suspension of clay increasing amounts of alum be added, there is a gradual cessation of this movement, a clumping together of the particles and finally coagulation and precipitation. At the point of precipitation there is no Brownian movement.

If a beam of light be passed through a dust-laden air, the dust particles become luminous and visible to the eye. Likewise if light rays be passed through a perfectly clear solution of colloidal iron or silicic acid, the minute particles will reflect light and the solution appear turbid. If the colloid is coagulated and allowed to settle, the solution no longer appears turbid. This phenomenon is known as the Tyndall effect and is shown in figure 1. In this photograph both bottles contained a solution of colloidal iron, but the one on the right was coagulated by the addition of tap water several hours prior to the taking of the picture. Projecting through each bottle are four beams of light but only in the one containing the uncoagulated iron colloid are they visible; in the other there are no particles to reflect the light rays. Figure 2 shows that a solution of colloidal iron is clear although dark in color.

These tiny invisible particles which will pass through the pores of ordinary filter paper, carry electrical charges and will move towards the positive or negative pole when subjected to an electric current. Iron and aluminum hydroxides are positive and clay and silicic acid negative. In dealing with negatively charged particles the most active coagulants are the trivalent cations, aluminum and iron, next the bivalent cations, calcium and magnesium, and lastly univalent cations of sodium, potassium and hydrogen.

If a small amount of alum be dissolved in a large amount of water containing carbonate or bicarbonate, there is a reaction in which

the aluminum of the alum passes from an ionic state into probably colloidal condition as aluminum hydroxide, and then into an insoluble gelatinous form commonly referred to as "floc" by the water works operator. If increasing amounts of colloidal aluminum hydroxide or alum be added to clay in suspension there is a diminution in the charge on the clay particles, then neutralization followed by

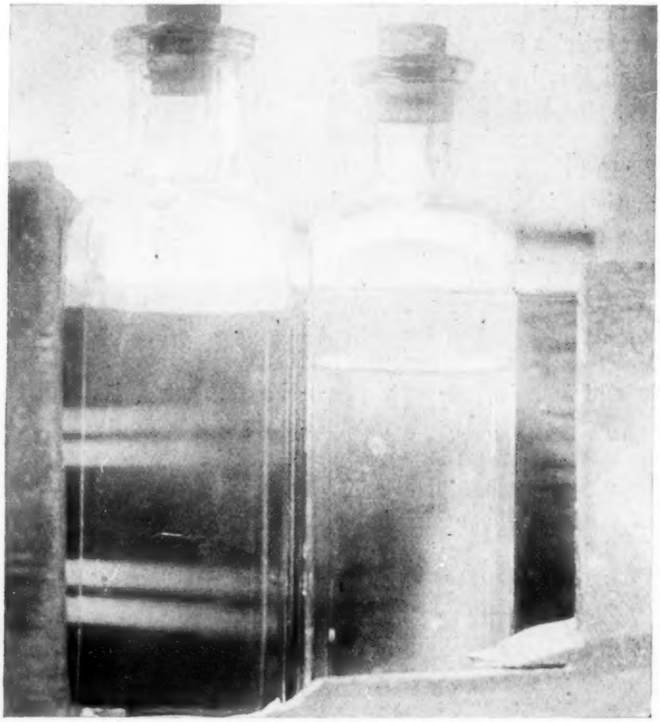


FIG. 1. TYNDALL EFFECT PRODUCED BY COLLOIDAL IRON AND ABSENCE OF THIS EFFECT WHEN COAGULATED AND SETTLED.

coagulation, and when an excess is added a reversal in the sign of the charge on the colloidal material.

Another property of colloids which is quite important is their power of absorbing colloids and fine particles such as bacteria, clay, coloring materials, etc. It is this property of the slime on the sand in filters and on the stones in contact beds, that results in the purification of the liquid passing through them.

Coagulation of clay suspensions. In water purification, the aim is the removal of a very small amount of clay or silica from a large amount of water. It is clearly evident from a study of dilute clay

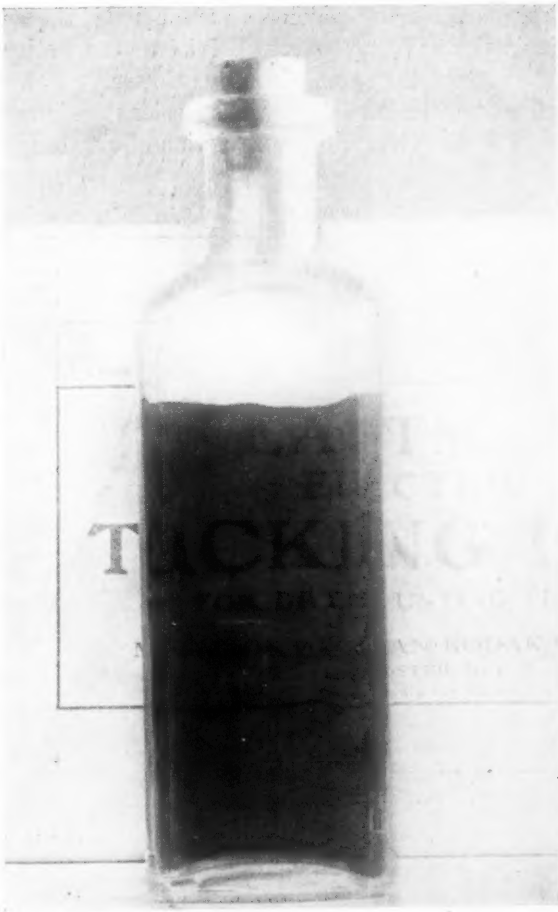


FIG. 2. PHOTOGRAPH OF PRINTING TAKEN THROUGH A COLLOIDAL SOLUTION OF IRON.

suspensions and colloidal silicic acid that the physical state of the substances and their chemical properties must be taken into consideration and the factors which influence them, i.e. (1) degree of dispersion, (2) the presence of the protective colloids and absorbed

substances, (3) magnitude and kind of electric charge, (4) the liquid or dispersing medium, (5) the ionic content of the liquid, (6) the concentration, (7) the temperature, and (8) the speed of reaction of added substances.

In discussing experiments which were conducted in the laboratories of the Illinois State Water Survey Division, the author will endeavor to show, first, the effect of various electrolytes or salts upon the rate of sedimentation of clay suspensions and, second, the effect of these electrolytes on the coagulation of clay suspensions by

TABLE 1

Electrolytes arranged in the order of their efficiencies as coagulants

ELECTROLYTE	1 MILLIGRAM EQUIVALENT EXPRESSED IN PARTS PER MILLION
Aluminum sulphate (alum) (17 per cent Al)	52.9
Ferrous sulphate, $FeSO_4$, $7H_2O$	139.0
Calcium hydroxide (hydrated lime) CaOH	37.0
Barium hydroxide, $Ba(OH)_2$	85.8
Calcium chloride, $CaCl_2$	55.5
Magnesium sulphate, $MgSO_4$	60.2
Calcium sulphate, $CaSO_4$	68.0
Magnesium bicarbonate, $Mg(HCO_3)_2$	73.2
Calcium bicarbonate, $Ca(HCO_3)_2$	81.0
Magnesium carbonate, $MgCO_3$*	42.2
Calcium carbonate, $CaCO_3$*	50.0
Sodium chloride, NaCl	58.5
Sodium sulphate, Na_2SO_4	71.0
Sodium bicarbonate, $NaHCO_3$	84.0
Sodium carbonate Na_2CO_3	106.0
Sodium hydroxide, NaOH	40.0

* This salt has little effect because of its low solubility

alum in the presence and absence of silicic acid or silicates. Suspensions of Tennessee ball clay were used, having turbidities of 400 and 420 parts per million and coefficients of fineness of 0.81 and 0.79. Reagents were added to 100-cc. portions of the suspension and thoroughly mixed by shaking one minute. The sample was then allowed to remain perfectly quiet and the turbidity determined at a point ½ inch below the surface at appropriate intervals of time. The electrolytes used are arranged in the order of their efficiencies as coagulants, when present in concentrations shown. At this point it might be well to state that the same reagent at one concentration

may disperse the suspended materials, thus preventing them from settling, and at another concentration cause the particles to collect together, producing coagulation.

The quantities of chemical used are expressed in milligram equivalents instead of parts per million because this is the most logical method of comparing chemical activity. An equivalent weight may be defined as the quantity of the radical or ion which combines with or will displace eight parts of oxygen; a milligram equivalent is one one-thousandth of one equivalent. One milligram per 1000 cc. of water is equivalent to one part per million. Table I shows the value of 1 mgm. equivalent of the various electrolytes in parts per million.

The salts arranged according to their efficiencies as coagulants are aluminum sulphate, ferrous sulphate, calcium and barium hydroxides, calcium chloride, magnesium and calcium sulphate, magnesium and calcium bicarbonate. The coagulating powers of calcium and barium hydroxide are practically the same and the ratio of the coagulating powers of aluminum to that of these ions is about five to one (see figs. 3 and 4). Sodium chloride has little effect until its concentration becomes large. Acid has little effect up to a concentration of 0.35 mgm. equivalent but higher amounts will coagulate. Sodium hydroxide, carbonate, acid carbonate and sulphate have at first a stabilizing influence followed by a coagulating effect, the hydroxide showing this action the greatest and the sulphate the least (fig. 4). When clay suspensions containing the above mentioned electrolytes are coagulated with alum, we find that salts of calcium and barium aid coagulation, while those that disperse, sodium bicarbonate, carbonate, sulphate and hydroxide, retard coagulation (fig. 5). With a given sodium hydroxide content and the addition of graded amounts of alum, there is first dispersion, then coagulation followed by a second dispersion phase (not as stable as the first) and finally coagulation (see fig. 6). As the content of sodium hydroxide is increased, additional amounts of aluminum sulphate must be added in order to produce coagulation and to combat the dispersive power of the hydroxide or sodium compound.

The concentration of chemicals necessary to produce coagulation does not vary with the alkalinity of the solution but seems to be a function of the concentration of hydroxyl ions (obtained from lime or carbonates) and alkali metal (sodium and potassium) ions as well as the cations and their valencies. A water containing large amounts

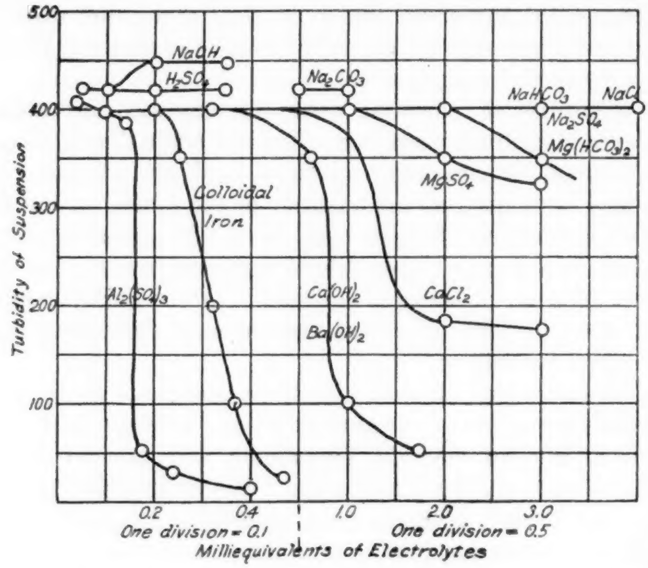


FIG. 3. EFFECT OF ELECTROLYTES ON THE COAGULATION AND SETTLING OF CLAY SUSPENSIONS. SETTLED 1 HOUR.

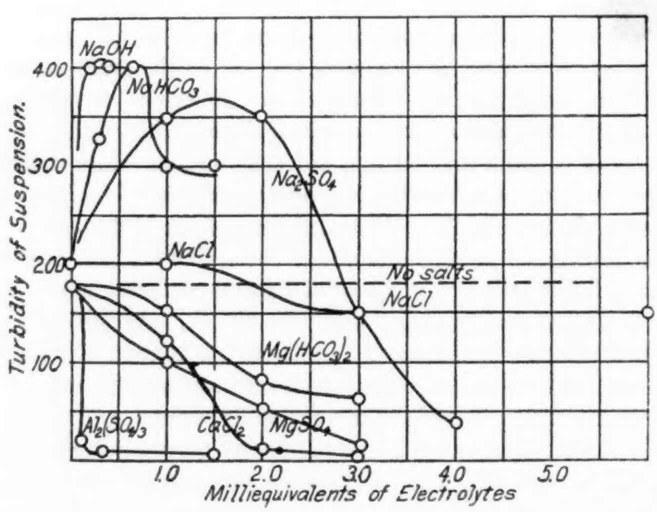


FIG. 4. EFFECT OF ELECTROLYTES ON THE COAGULATION AND SETTLING OF CLAY SUSPENSION. SETTLED 14 HOURS.

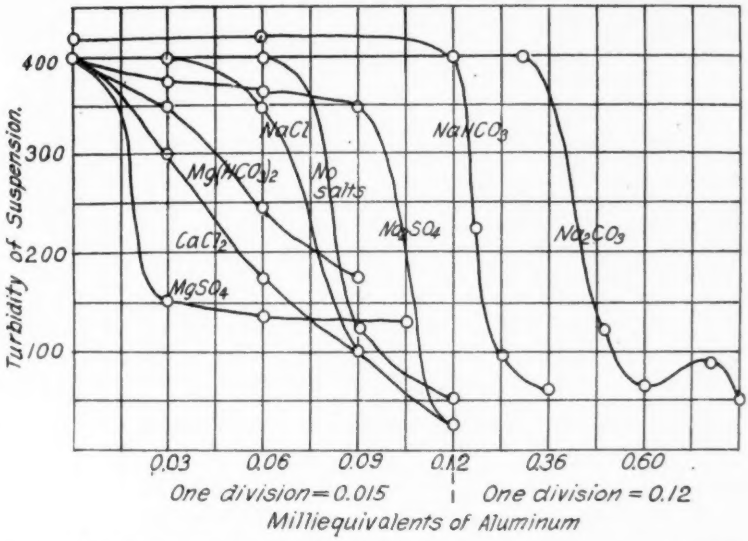


FIG. 5. EFFECT OF ADDING 1 MILLIEQUIVALENT OF ELECTROLYTES ON THE COAGULATION OF CLAY SUSPENSION BY $Al_2(SO_4)_3$. SETTLED $1\frac{1}{2}$ HOURS.

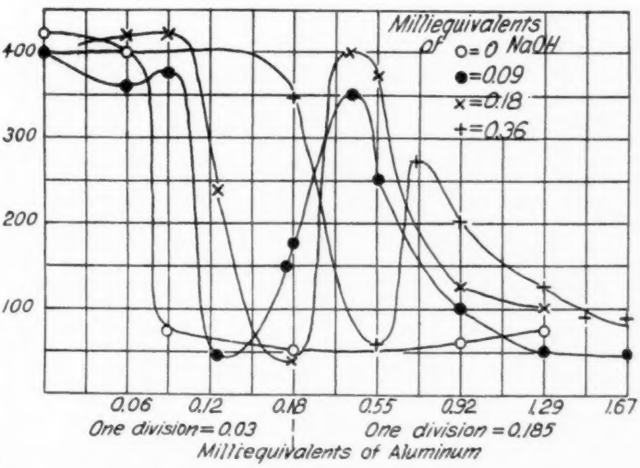


FIG. 6. EFFECT OF NaOH ON THE COAGULATION OF A CLAY SUSPENSION BY $Al_2(SO_4)_3$. SETTLED $1\frac{1}{2}$ HOURS.

of sodium salts except sodium chloride and a very small amount of calcium or magnesium salts is much more difficult to clarify than one wherein the magnitude of the concentrations is reversed.

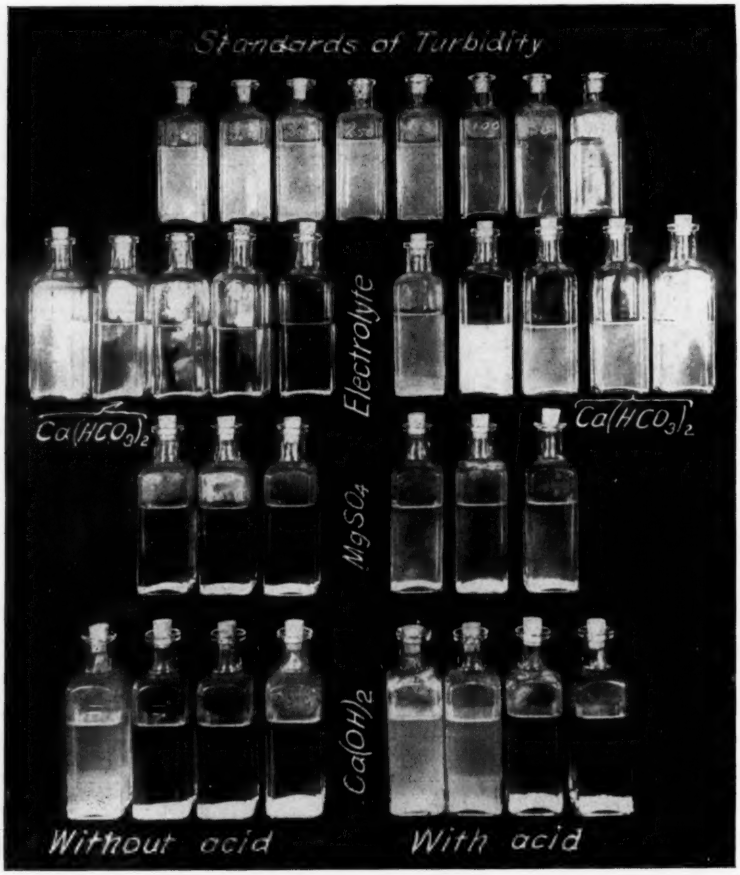


FIG. 7. EFFECT OF COLLOIDAL SILICIC ACID ON THE COAGULATION OF CLAY SUSPENSIONS BY $Al_2(SO_4)_3$.

Now when silicic acid is present the effect is very similar to that produced by the sodium compounds and in all cases more alum is needed to produce clarification than is used when the silica colloid is absent. Figures 7 and 8, taken five days after the addition of alum, show this well. To those samples on the right were added 62

parts per million of SiO_2, and to those on the left none. These solutions were coagulated by the addition of increasing amounts of aluminum sulphate so proportioned that at one end of the series the suspension was partially coagulated and at the other completely clarified; the amounts of aluminum sulphate though varying

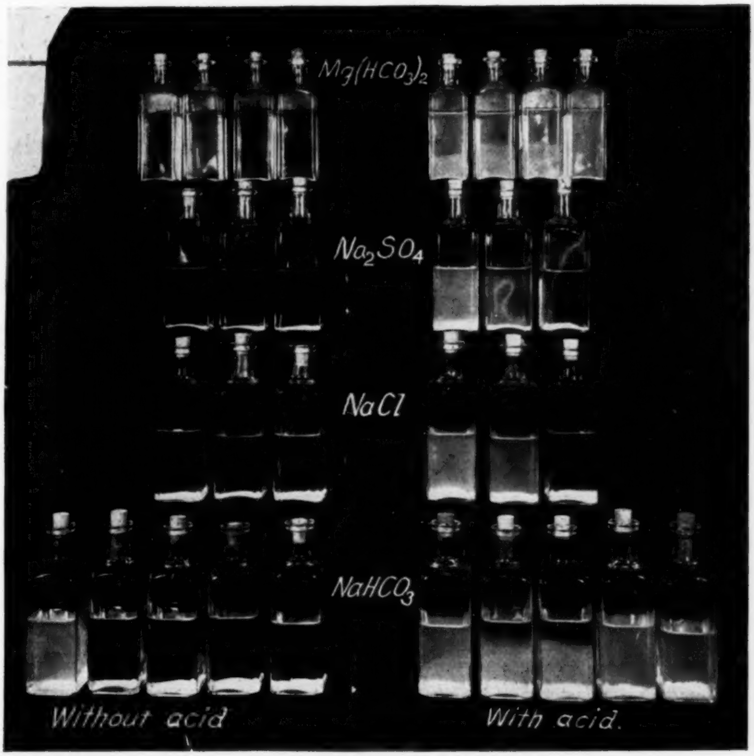


FIG. 8. EFFECT OF COLLOIDAL SILICIC ACID ON THE COAGULATION OF CLAY SUSPENSIONS BY $Al_2(SO_4)_3$.

with the different salts are the same in any particular salt. In general the amount of aluminum required to coagulate, per unit amount of silicic acid present, is proportionally larger at low than high concentration. Colloidal silicic acid does not seem to stabilize or disperse the clay suspensoid nor does it influence the rate of sedimentation; in this respect it differs from the alkalies.

Experiments on removing silicic acid showed that it is most efficiently precipitated from solution by the trivalent ions of aluminum and iron, next the bivalent calcium, magnesium and barium, and not precipitated by the univalent sodium and potassium except at very high concentrations. Also that the maximum removal of silicic acid by aluminum hydroxide occurs when the water contains a concentration of hydrogen ion of 1×10^{-8} grams of hydrogen per liter; at this concentration a bright cherry red color is produced when phenolphthalein is added.

Applications. Thus the proper treatment for the removal of colloidal silicic acid is to slightly over-soften with lime and to coagulate

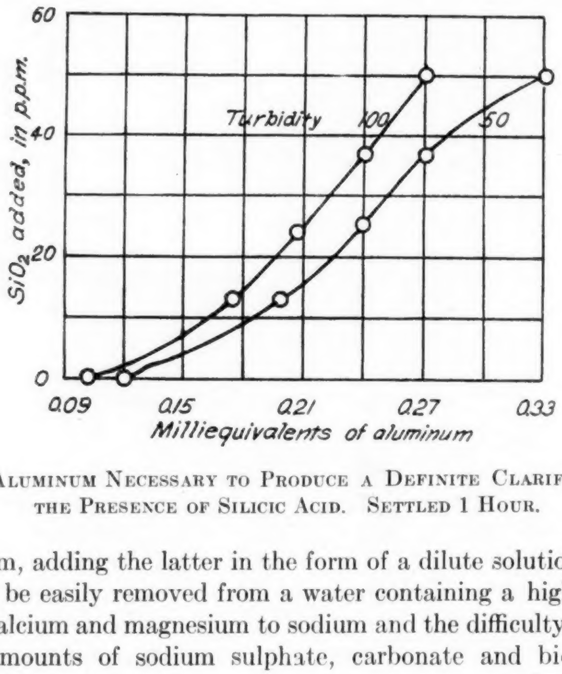


FIG. 9. ALUMINUM NECESSARY TO PRODUCE A DEFINITE CLARIFICATION IN THE PRESENCE OF SILICIC ACID. SETTLED 1 HOUR.

with alum, adding the latter in the form of a dilute solution. Silicic acid can be easily removed from a water containing a high proportion of calcium and magnesium to sodium and the difficulty increases as the amounts of sodium sulphate, carbonate and bicarbonate become larger.

In the coagulation of water containing colloidal clay, the stability of a clay suspension seems to be intimately related to concentration of sodium and potassium, carbonate and sulphate. The amount of alum will be greater the larger the concentration of these and less as the ratio of Ca + Mg to Na increases. As the silicic acid increases more alum is required. At a concentration of 20 parts per

million from 0.8 to 1.6 parts per million of alum per 10 parts of SiO_2 are required to combat the influence of the silicic acid (fig. 9).

Waters containing bivalent ions when treated with alum give a sharp abrupt reaction, an increase of 2.6 parts per million of alum coagulates, but when silicic acid or alkalies are present, other factors being constant, a much larger amount of alum is necessary to produce the same clarification and the abruptness of the reaction becomes less as the amount of the silicic acid and alkalies approaches a certain maximum, where the magnitude of the change produced per unit amount of alum is much smaller than in the former case. This phenomenon is exactly similar to that which occurs when

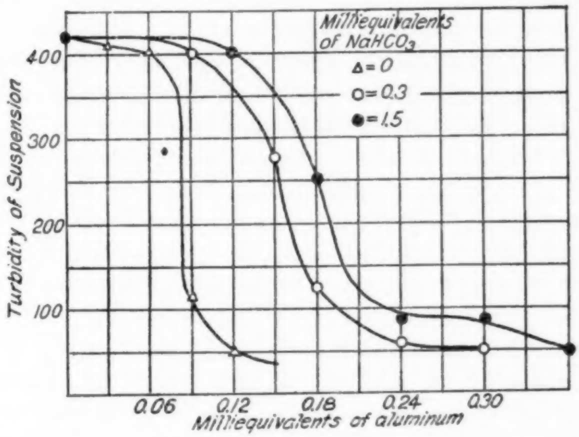


FIG. 10. EFFECT OF $NaHCO_3$ ON THE COAGULATION OF CLAY SUSPENSION BY $Al_2(SO_4)_3$. SETTLED 1½ HOURS.

"colloidal waters" are coagulated by alum and lime. It is this slowness of reactions that misleads many operators into the pitfalls of undertreating this class of waters. In figure 10 the alum required to coagulate was 6.5 parts per million but in the presence of 25 parts per million of sodium bicarbonate 13 parts per million was added before coagulation started. These experiments justify the addition of an excess of calcium hydroxide and allowing it to react with the material in the water for some time, 6 to 12 hours before the addition of alum or ferrous sulphate. This procedure has been effective in purification of water from the Arkansas River at Little Rock, Arkansas, when the suspended material is in a colloidal condition.

In this case river water containing a turbidity due to colloidal material of 200 to 600 parts per million and an alkalinity near 100 was effectively handled by dosing with lime (3 to 4 grains per gallon) until there was an alkalinity to phenolphthalein of 30 to 40 parts per million (a cherry red color) and a methyl orange alkalinity of 60 to 80 parts per million. This water was passed through a sedimentation basin of six to twelve hours retention period, in which some sedimentation resulted, and was then coagulated with about 1 grain of alum or ferrous sulphate. When treated in the regular manner the water was passed through this sedimentation basin, and 5 to 6 grains per gallon of alum and 2 to 3 grains of lime added before coagulation were effective. Even with this large amount of coagulant the water was in very poor condition to filter, while in the former case the water was clear and contained large and well formed flocs, but of course there was an alkalinity to phenolphthalein of 10 to 20 parts per million in the finished waters.

WATER WORKS IMPROVEMENTS AT AKRON, OHIO[1]

By G. Gale Dixon[2]

Water supply in Akron has been complicated during recent years by a very rapid growth in the city, so rapid that many persons who should be living in it in order that the large industrial population may be surrounded by normal conditions are actually unable to find accommodations. This condition is so unusual and affects estimates of the population to be supplied with water in the future so materially that it deserves particular attention. In 1919 the population was 175,000 and the ratio of this total population to the number of persons engaged in the city's industries was 2.5. In 1910 the population was only 69,000 and its ratio to industrial employees was 3.5, about the same ratio as existed in Paterson, N. J., and Bridgeport, Conn., in that year. The ratio of 3.5 is about the smallest which is possible when the city has homes for the families of all its industrial workers and affords adequate public utilities, stores, eating places, amusements, schools, professional men and other elements of a reasonably balanced municipality. If all the industrial employees now in Akron were able to bring their families to the city and give them the facilities which they are justified in expecting in a thriving American city of this class, the population would be about 250,000 today. This is clearly shown by the ratio of total population to industrial employees in other manufacturing cities; Pittsburgh, Pa., population 533,900 in 1910 and a ratio of 5.1; Indianapolis, 116,100 and 5.0; Columbus, Ohio, 181,500 and 5.4; Worcester, Mass., 146,000 and 4.1; Camden, N. J., 94,500 and 4.3. It is obvious that a properly balanced condition of the population can only be realized by expanding housing facilities and public utilities and improvements more rapidly than the industries develop. The improvement of the water works which the voters authorized last year was based on this view of the existing conditions and is the minimum which those in charge of the work regard as meeting the unusual situation in the city.

[1] Discussion of this paper is requested and should be sent to the Editor.

[2] Chief Engineer, Bureau of Water Works Improvement, Akron, Ohio.

The very rapid growth of the city is shown in figure 1, which also shows the rate of growth of a number of other American cities after they attained a population of 200,000. Akron's recent growth has never been paralleled during any great period of time by any city except Chicago, and the lack of natural advantages in the Akron district makes a long continuation of such rapid development unlikely. It is certain, however, that with an adequate program for housing and public improvements, the continued expansion of industries will raise the population to very nearly 300,000 by 1925. It is believed that the district can be developed to support a popula-

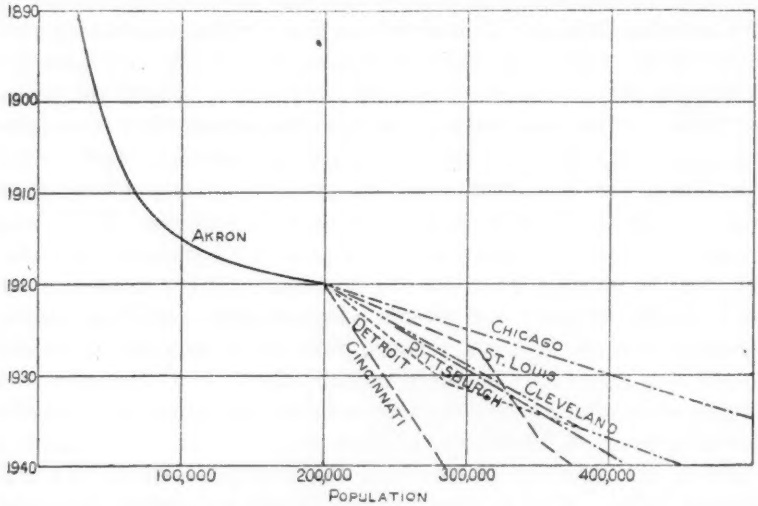


Fig. 1. Growth of Population of Akron and of Other Cities After Reaching 200,000 Population

tion of a million, but such numbers need not be considered at this time.

Municipal water supply in Akron dates from April 1, 1912, when the city took over the plant of the Akron Water Works Company, for which it paid $815,000. The supply was both poor and inadequate and the plant was not large enough for the needs of that day. Work was immediately begun on new works under the direction of F. A. Barbour and E. G. Bradbury, consulting engineers, and in August, 1915, water was delivered by them to the city. The supply is obtained from the Cuyahoga River, which was dammed about 3 miles above Kent. The drainage basin above the dam has an

area of 206 square miles. The reservoir, called Lake Rockwell, holds about 2,385,000,000 gallons and can be relied on to supply 30,000,000 gallons daily in time of drought. By placing flash-boards on the dam the water can be raised 3 feet and the supply increased to 35,000,000 gallons daily, a quantity sufficient for a population of about 300,000. The watershed is probably capable of further development at reasonable cost to furnish a supply of 100,000,000 gallons daily.

The water flows from the reservoir to a purification plant through a 48-inch cast iron pipe line about half a mile long. In order to maintain a gravity flow of large quantities of water through the purification plant a parallel raw water line must be constructed, provision for which was made in the original construction work.

Before filtration the water, after treatment with alum, passes through underground storage basins of 2,000,000 gallons capacity. This capacity is inadequate for satisfactory sedimentation at the present rate of operation. In 1919, when the raw water carried a large quantity of microscopic vegetable matter, the period of operation of filters between washings was reduced at times to 45 minutes and it was necessary to use all the filters to meet the demands for water. It is accordingly proposed to increase the sedimentation basins to a total capacity of 4,700,000 gallons. This will give a two-hour detention period for the gross capacity of the plant after being enlarged as proposed, or about three hours for the estimated average demand.

The filtration plant has fifteen units of 2,000,000 gallons each, of the rapid sand type. Allowing for one unit in reserve and 10 per cent of the water to be used in the operation of the plant, the net maximum capacity is 25,000,000 gallons daily. This is equivalent to the maximum demand on the plant during a year when the consumption averaged about 20,000,000 gallons daily. It is expected that this demand will be reached or exceeded during the current year. Plans are accordingly being made for the construction of eleven more units of the same size, which will give a total gross capacity of 52,000,000 gallons, enough to maintain satisfactorily peak load conditions during a year with an average consumption of 35,000,000 gallons daily.

The pumping station serves four purposes, lifting water to the filters when the level in the storage reservoir is too low to permit the usual gravity flow through the filter plant, forcing the purified

water to the city through an 11-mile force main, furnishing electric current for lighting and power about the plant, and supplying steam for the equipment to perform the functions mentioned.

There are two low-lift pumps, one of 17,000,000 gallons daily capacity and one of 25,000,000 gallons capacity. Another 25,000,000-gallon pump, with perhaps a fourth of smaller size, will bring the present equipment up to the capacity of the enlarged purification plant. The station contains two triple-expansion pumping engines with a normal rated capacity of 14,000,000 and 15,000,000 gallons respectively, and a 10,000,000-gallon turbo-centrifugal pump, for the high-lift service. With continued careful operation this plant will suffice for a year having an average consumption of about 24,000,000 gallons. The present plan is to add a 20,000,000-gallon triple-expansion pump. Counting this as a reserve and running the three present pumps at their maximum capacity, which is 7,000,000 gallons above their normal capacity, an output of 46,000,000 gallons daily can be maintained, equivalent to the peak load during a year with an average consumption of 35,000,000 gallons.

The original boiler plant had three 200-horse power hand-fired boilers and in 1918 two 300-horse power boilers were added. It is proposed to substitute two 300-horse power boilers for the three small units, install mechanical stokers under all the boilers and put in an induced draft fan system. Later another battery of 300-horse-power boilers must be installed. The improvements now proposed also include increasing the coal storage, installing a full equipment of economizers and rearrangements of the plant which will remedy its overcrowded condition in some places.

The original force main was a 36-inch lock-bar steel pipe. About $2\frac{1}{3}$ miles of its length have already been paralleled by a 48-inch pipe of the same type and about 4 miles more are now under construction. The new line is being cross-connected to the old one at intervals of about a mile. The remainder of the new line will be laid next year. The difference in elevation between the pumping station and the distribution reservoir in East Akron is 165 feet. The high-lift pumps and force main were designed for a maximum head of 290 feet at the pumps, leaving about 125 feet pressure head at the pumping station available for overcoming friction in the force mains. Tne original 36-inch pipe had sufficient capacity with 290 feet total head at the station to handle the peak loads of a year with an average consumption of about 16,000,000 gallons per day.

The result of reinforcing $2\frac{1}{3}$ miles of its length with a 48-inch pipe has been to raise its capacity for the peak of a year with 18,000,000 gallons average daily draft, a rate which has already been exceeded, showing that the force main is obviously in need of the reinforcement now in progress. The two mains, 36 and 48-inch, will deliver 35,000,000 gallons daily with a total head of 220 feet on the pumps, which is the head for maximum efficiency for the pumps, while a peak load of 46,000,000 gallons per day will increase the head to but 250 feet.

The water is delivered to a distributing reservoir in East Akron which holds about 20,000,000 gallons, approximately the average daily consumption at present. The city has bought land near this reservoir for additional basins which will bring the total capacity to about 100,000,000 gallons. The present improvements contemplate the construction of a 30,000,000 gallon basin, making the total storage capacity 50,000,000 gallons, or about the maximum 24-hour demand during a year with an average consumption of 35,000,000 gallons.

These notes of work to be done as rapidly as possible must be read in the light of the fact that it was only five years ago that the new works were put in service, and this extensive additional work is not the first enlargement of the municipal system. The city grew so fast that in 1917 $3,110,000 had to be provided, part of which was used in bringing the supply system to the condition just described and part in laying about 70 miles of street mains, installing a universal meter system and providing booster pumps and elevated water tanks for two high-service districts. Today there are 120 miles of street mains to be laid in order to give the service which should be afforded, and the improvement program provides for at least 30 miles of this work annually. The various stages in which it is proposed to carry on the work are scheduled in figure 2.

While the engineering features of the new work are interesting, the business aspect of the Akron water works is possibly still more interesting. Figure 3 shows the population and water consumption of the city for the last ten years and two estimates for future conditions, one assuming that the city reaches 300,000 population in 1925 and one that it attains this size in 1930. The capacity of the present elements of the water works is also shown. It will be seen that in 1918 and 1919 the consumption and population curves have been drawing together, indicating a reduction in the per capita con-

sumption of water. This condition may be partly due to the reduction of waste by universal metering, but the main factor is probably the compliance of manufacturers with requests to hold down

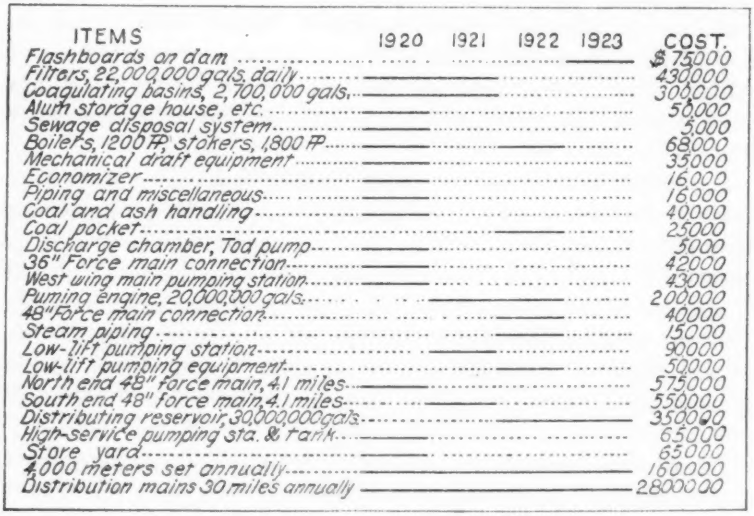


FIG. 2. PROGRESS SCHEDULE, AKRON WATER WORKS IMPROVEMENTS

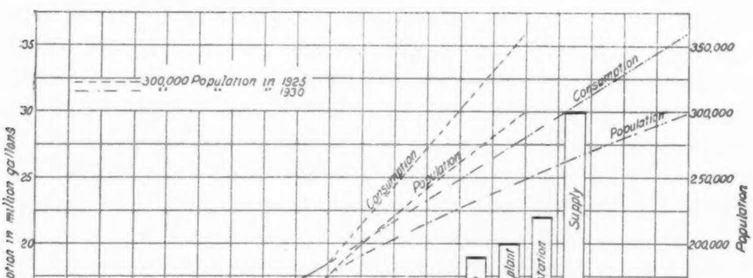


FIG. 3. POPULATION AND WATER CONSUMPTION CURVES, AKRON

their consumption to the minimum. The program of new work is based on the use of 120 gallons per capita, which is believed to be moderate for Akron conditions.

Information regarding past financial conditions, furnished by H. H. Frost, superintendent of the Bureau of Water Supply, is shown on figure 4. Lines have been drawn extending these data into the future to indicate the financial conditions which will result from proceeding with the construction program, with income (based on

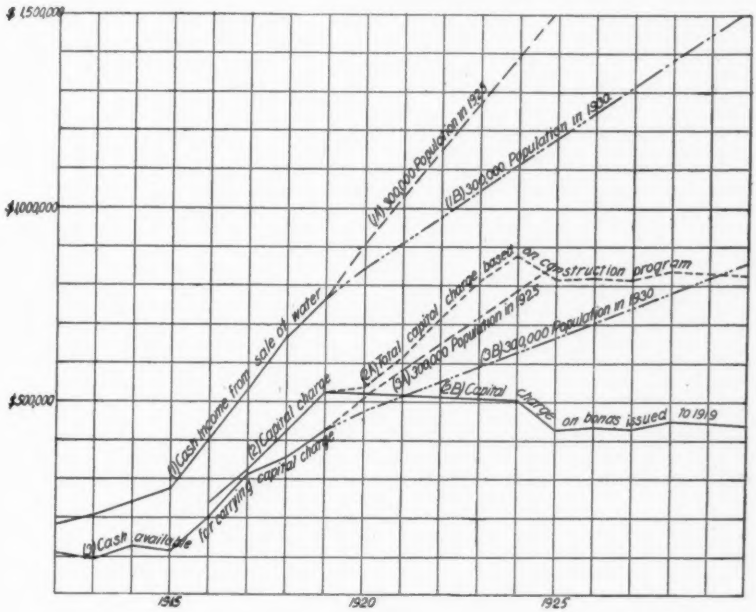


FIG. 4. FINANCIAL DATA REGARDING AKRON IMPROVEMENTS

Line (1) Extensions (A) and (B) are based on income of $115 per million gallons of water at the current rates.

Line (2) is based on the standard amortization method of retiring sinking-fund bonds.

Line (3) Cash Available for Carrying Capital Charge is the difference between Cash Income (Line 1) and the cost of operation and maintenance. Extensions (A) and (B) are based on a cost of $50 per million gallons for the cost of operation and maintenance.

No credit is taken in this diagram for service supplied free to other city departments.

present water rates) increasing according to two different assumptions, first, the population increasing to 300,000 in 1925, and, second, the population reaching that figure in 1930. The diagram covers cash income only, no credit being shown for water supplied to the city or to charitable institutions.

It will be seen that on the first assumption there will be a deficiency in "cash available to carry capital charge" until 1925, substantially equal to the deficiency of the last few years. With the slower rate of growth this deficiency is larger and continues until 1930.

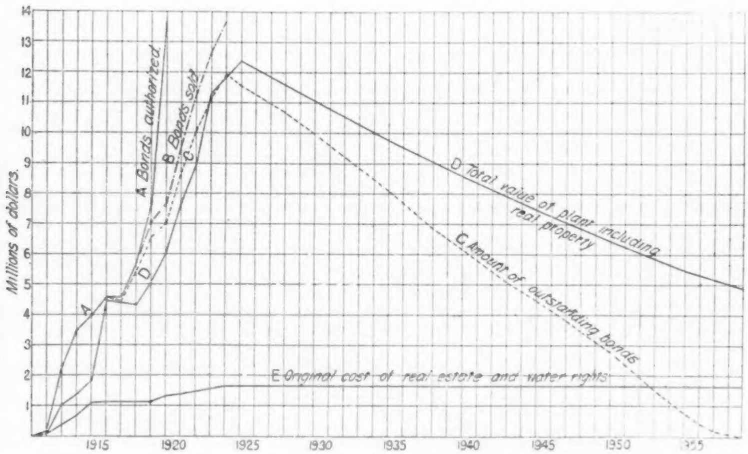


FIG. 5. ESTIMATED ASSETS AND LIABILITIES TO TIME OF FINAL RETIREMENT OF BONDS

B. Assumes bonds sold in accordance with construction program.

C. Assumes $6,685,000 to be issued as 5 per cent 35-year serial bonds arranged for equal total annual carrying charges. The average term of bond issues to 1919 (7,005,000) was 27.9 years, and the addition of $6,685,000 on the preceding terms raises the average to 31.4 years.

D. Assumes straight-line depreciation of structures and improvements at the following named years of useful life: Reservoirs, impounding and distributing, 75; purification plant, pumping station, brick and concrete buildings, 40; cast iron pipe lines and appurtenances, 75; steel pipe and tanks, 35; boiler plant, 15; vertical triple-expansion pumping engines, 40; other pumping equipment, 25; service meters,15; dwellings, 15. Note that 11.8 per cent of the investment is in real property and that the average life of structures and improvements as set forth is 57.6 years.

E. Real property has been assumed of constant value at its original cost.

A continuation of the policy of compensating the water department through the sinking fund commission for water supplied free for public purposes and fire protection will wipe out this deficiency in the future as it has in the past and continue the department self-supporting at the present water rates. This is shown by the fol-

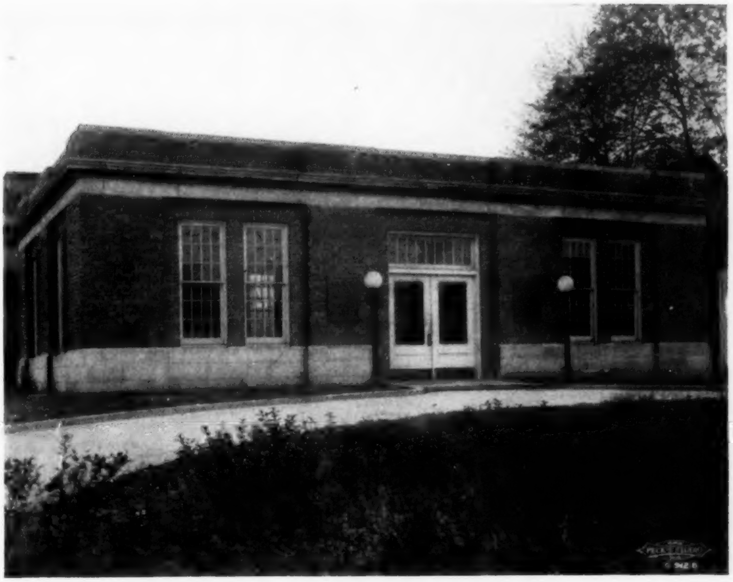


FIG. 6. EXTERIOR OF HIGH-SERVICE PUMPING STATION

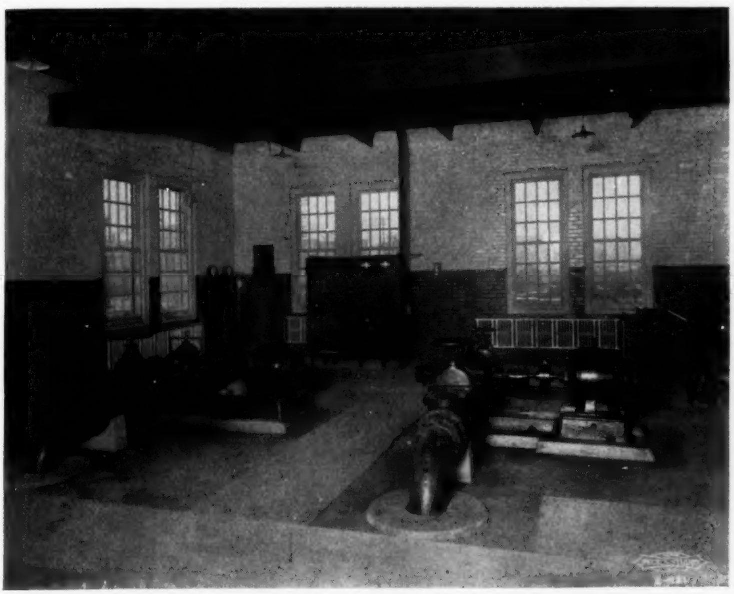


FIG. 7. INTERIOR OF HIGH-SERVICE PUMPING STATION

lowing figures, which assume allowances for free water to be made at the rate of $12 per million gallons of total water consumption.

(1) With the population increasing at the rate of 20,000 per year, reaching 300,000 in 1925, the department will operate continuously "at a profit," accumulating a surplus of about $400,000 by 1925. This assumes that no further bond issues are voted during this period.

(2) With the population increasing at the rate of 10,000 per year, reaching 300,000 in 1930, the department will operate with a deficit from 1921 to a maximum accumulation of indebtedness of $200,000 in 1925, after which date the deficit will be reduced and in 1929 there will be a surplus of about $100,000.

The allowance for free water and for fire service at the rate of $12 per million gallons of total consumption, as used above, is in substantial accord with the report of the State Auditor for the last two-year period covered by his reports, in which the "total free water service" was estimated at $145,848.46.

Figure 5 is a diagram prepared for the use of the city council in determining the life of water works bonds, which was finally fixed at 30 years.

Figures 6 and 7 are views of the exterior and interior of a high-service pumping station just built in the highest grade residential district in the city. The equipment consists of two motor-driven centrifugal pumps, each rated at 1,000 gallons per minute, arranged for automatic operation. Space is left for two larger pumps which will probable be needed later. The pumps are driven by Wagner motors controlled by a Golden-Anderson stop-starter controlling altitude valve, operating through relays on the pumping station switchboard. There are two stop-starters, throwing the pumps in at successive intervals in the drop of the water level in the water tank into which the station pumps. There is also a cross-over switch in the station so that either pump may be set to start first. The elevated tank was erected by the Chicago Bridge and Iron Works and contains 350,000 gallons, supported on a tower 75 feet high.

ELEMENTS OF THE THEORY UNDERLYING THE DISINFECTION OF WATER BY ULTRA VIOLET LIGHT[1]

By Gordon M. Fair, S.B.[2]

The steadily increasing use of ultra violet light for the disinfection of water supplies, large and small, seems to indicate that the art is sufficiently well advanced to warrant a discussion of the theory upon which it is based. This theory, recruiting its hypotheses and proofs from the basic sciences of physics, chemistry, and biology, deals with the nature and general physical properties of ultra violet light and with the photoabiotic effects which it is able to produce, so far as any of these are related to the application of ultra violet light to water disinfection. It is hoped that an elementary discussion of this nature will be of interest to water works engineers, and that it will be instrumental in dispelling the clouds of mystery which enshroud to so many this most natural of all methods of water disinfection.

The advance in our knowledge of the theory of ultra violet light is due especially to Schumann, Lyman, and other physicists who investigated the spectroscopy of the ultra violet, and to Bovie and his coworkers, who reported upon its biological activities, while the list of names of those who have been connected with its scientific application to water disinfection includes those of many scores of French, German, and American workers.

Radiation. The word "light" is familiarly associated with the sensation of vision alone. If, however, the electromagnetic waves which produce the sensation of light when they fall upon the eye and therefore become *post facto* "light or luminous radiations" be allowed to fall upon an opaque body, the same may be warmed and the radiations become "radiant heat." If, on the other hand, they fall upon a living green leaf or a photographic plate, they may produce chemical changes and thus become "actinic" or "chemical" rays. All three names—luminous, heat, or actinic radiations—may therefore be given to the same wave train, depending upon the

[1] Discussion of this paper is requested and should be sent to the Editor.

[2] Instructor in Sanitary Engineering, Harvard University, Cambridge, Mass.

effects which it is able to produce, and the term "light" which, strictly speaking, would apply only to radiations exerting the sensation of light, is used in a figurative sense to include the entire range of radiations which are alike in their general properties. But while the rays are traveling through space there is neither heat, light, nor chemical activity—merely wave motion. The frequency of this motion is inversely proportional to the wave length, permitting a constant velocity of travel of 300,000 kilometers or 186,000 miles per second. Waves which differ in their frequency differ to some extent in the degree of their power to produce heat, light, or chemical activity. The degree of this power is detected by the vibrations which they set up in the objects upon which they fall, just as when a note played on a musical instrument causes the same note on a neighboring stringed instrument to sound. It is merely due to a special property of the eye, therefore, that some of the radiations excite the sensations of light while others do not. Waves vibrating at less than 392,000,000 vibrations per second are too slow to affect the eye or produce chemical changes; they are called dark-heat-waves, while those vibrating more than 757,000,000,000 per second are too rapid to act upon the eye, but may affect chemicals; they are called actinic or ultra violet waves. The activity of the latter in bringing about chemical changes in both living and lifeless matter may be likened to the effect produced by singing its own note into a resonant tumbler, making it vibrate, shiver, and even break into pieces. The waves between the two limits of frequency given constitute the luminous radiations which produce a sensation of light upon the eye.

If a beam of monochromatic light be passed through a slit, the light issuing through the slit being caused to pass through a glass prism, it will be refracted and an image of the same color as that of the original beam of light will appear at some place on a screen held parallel to one side of the prism. If now a beam of white light be made to take the same path, it will form a number of colored images or a many colored band of light, each colored image of the slit being arrayed in the order of the frequency of its waves, the slowest ones (the red waves) being least refracted and the quickest ones (the violet waves) being most refracted. Between these limits we have the other colors of the rainbow, forming together the visible part of the spectrum. But the spectrum extends beyond the images of the visible rays. The slower invisible dark-heat-rays, being less refran-

gible, appear beyond the red, forming the infra red end of the spectrum; they are detected by a thermometer or other sensitive heat measuring device. The more rapid, invisible, actinic rays, being more refrangible, appear beyond the violet, forming the ultra violet end of the spectrum; they are detected by a photographic plate or by fluorescence.

It is not usual to define the range of a wave train by the limits of its vibration frequencies. The wave lengths (λ) of the train, which, since the velocity of travel is a constant, vary inversely as the vibration frequencies, are used in their stead. The unit of wave length chosen is sometimes the millimeter, sometimes the micron (1 μ = 0.001 millimeter), but ordinarily the Angstrom unit (1 Angstrom unit = 0.0000001 millimeter = 0.0001 μ). Table 1 gives the wave lengths of a number of radiations.

TABLE 1

Wave lengths of some radiations

	Angstrom units λ
Shortest waves observed by Lyman about	900
Schumann waves	1000
Shortest visible violet waves	3800
Violet about	4000
Blue	4500
Green	5000
Yellow	5800
Red	6500
Longest visible red waves	7500

Beyond the longest heat waves and below the shortest ultra violet waves there are a multitude of other electromagnetic radiations, such as the wireless waves, which are measured in hundreds of meters, and the Röntgen and gamma rays, which are measured in tenths or hundredths of an Angstrom unit.

Transmission. If the object upon which a train of waves falls is not capable of resonant vibration with the waves, they pass through the object, which is then said to be transparent to light of the wave lengths in question. No substance is transparent to radiations of all wave lengths—indeed, such a substance would be invisible. White fluorite, perhaps the most transparent substance known, allows the passage of heat, luminous, and actinic rays. Crystal alum is not transparent to heat rays but permits the passage of luminous and actinic rays. Silver leaf thick enough to be opaque

to luminous radiations passes ultra violet rays, while thin opaque pieces of vulcanite will allow radiant heat to pass. In general, matter decreases in transparency from the visible to the extreme ultra violet as the wave lengths decrease, until even highly rarified gases are opaque. When we pass beyond the light region, however, we find that as we approach the Röntgen and gamma rays (λ = 0.1 to 0.01 Angstrom units) this condition is reversed and that matter increases in transparency as the wave lengths decrease until in the region of the gamma rays even several centimeters of lead are transparent.

Absorption. If now a wave train falls upon an impervious body, i.e., one which is capable of resonant vibration with it, the progress of the train is arrested and the waves are either reflected or absorbed. The absorbed energy will effect a rise in the temperature of the body or other changes of a chemical or physical nature.

Absorption of ultra violet light by solids. The absorption of ultra violet light by solids, liquids, or gases is of prime consideration in its application to water disinfection. The source of ultra violet light is usually protected by a transparent envelope from direct contact with the water and the selection of some suitable material will influence qualitatively and quantitatively the radiations obtained as shown in table 2.

The selection of the protecting material is limited by: (1) its transparency to high frequency vibrations; (2) its ability to withstand immersion in water; and (3) its behavior under exposure to high temperature radiations from the source of light. Present experience favors the use of fused quartz. This mineral is obtainable in large homogeneous masses, is easily workable, and is extremely resistant to heat and water. The melting point of quartz is about 1700°C. Its linear coefficient of expansion is 0.39×10^{-6} cm. per degree Centigrade per centimeter as compared with 7.8×10^{-6} for glass and 7.5×10^{-6} to 13.7×10^{-6} for crystal quartz. It is transparent at all temperatures up to 900°C., when it changes to crystalline quartz or tridymite, an opaque mineral. The working temperatures, however, seldom exceed 300°C.

Absorption of ultra violet light by liquids. Quantitative measurements of the absorption of ultra violet light by water have been made by Kreusler, who apparently used a depth of two centimeters and found that 14.2, 24.5, and 68.9 per cent of radiations shorter than λ = 2000, 1930, and 1860 respectively were absorbed by this

TABLE

Absorption of ultra violet rays by solids

SUBSTANCE	THICKNESS	PER CENT ABSORBED	WAVE LENGTH, ANGSTROM UNITS	AUTHORITY
	mm.			
Common glass		100.0	3500	Lewis
Crown glass	10.0	Very strong	3100	Lyman
English borosilicate crown	2.0	100.0	2970	Zschimmer
Uviol glass	10.0	50.0	3050	Zschimmer
Uviol glass	1.0	50.0	2800	Zschimmer
Uviol flint	2.0	100.0	2850	Zschimmer
Uviol crown	2.0	100.0	2800	Zschimmer
Iceland spar	10.0	50.0	2800	Pflüger
Iceland spar	10.0	97.0	2140	Pflüger
Crystal quartz	10.0	5.8	2220	Pflüger
Crystal quartz	10.0	8.0	2140	Pflüger
Crystal quartz	10.0	16.4	2030	Pflüger
Crystal quartz	10.0	32.8	1860	Pflüger
Crystal quartz	2.0	100.0	1600	Lyman
Crystal quartz	0.2	Quite transparent	1450	Lyman
Fused quartz (probably impure)	2.8	100.0	2000	Pflüger
Fused quartz (pure)		Quite transparent	<1850	Lyman
Rock salt		4.5	2800	Pflüger
		30.0	1860	Pflüger
Fluorite	10.0	20.0	1860	Pflüger
Topaz	1.5	100.0	1575	Lyman
Gypsum	1.0	100.0	1650–1700	Lyman
Colemanite		100.0	1750	Lyman
Alum	1.0	100.0	1750	Lyman

TABLE 3

Absorption of Ultra Violet Light by Water

DEPTH	PER CENT ABSORBED	WAVE LENGTH, ANGSTROM UNITS	INCREASED DEPTH PER 100 ANGSTROM UNIT INCREASE IN WAVE LENGTH	AUTHORITY
cm.				
0.05	100	1729		Lyman
2.90	100	1860	2.21	Kreusler
8.10	100	1930	7.43	Kreusler
14.10	100	2000	8.57	Kreusler

depth of water. Lyman found that 0.5 millimeter of water cut off the spectrum at 1729 Angstrom units. If we apply to these results Lambert's law that each layer of equal thickness absorbs an equal fraction of the light which passes it, we obtain the figures given in table 3.

These results show clearly that with increased wave length the depth of water which will absorb all the rays is materially extended. Unfortunately, however, there are no accurate data on wave lengths greater than 2000 Angstrom units. If, however, the increased depth per 100 Angstrom unit increase in wave length were constant after passing 2000 Angstrom units, it would take 43 centimeters of water to absorb all waves shorter than $\lambda = 2500$ and 86 centimeters or 2 feet 10 inches of water to absorb all wave lengths less than $\lambda = 3000$. The actual depth would apparently be even greater. As the figures in table 3 refer to experiments made on pure water, a slight allowance must be made under practical conditions for the color and the turbidity of the water supply which is to be treated, the disinfecting value of the light varying with colors of different magnitude and tints and turbidities of different amounts and fineness. Grimm and Weldert, for example, found that turbidities due to milk had a very much smaller coefficient of absorption than turbidities due to clay. It has also been ascertained that yellow tints are less transparent than green ones. From experiments made with water relatively rich in coloring and suspended matter, the author is inclined to believe that the colors and turbidities of filtered waters are usually not sufficiently high to influence the results materially.

Absorption of ultra violet light by gases. The ultra violet radiations of the sun are of very feeble physical energy, because we receive them only after they have been filtered through the atmosphere which surrounds our earth to the depth of about 14,000 meters. Miethe and Lehman determined the limit of the solar spectrum at various altitudes from near sea-level to 4560 meters and arrived at the surprising result that the last trace of light action was independent of altitude at $\lambda = 2912$. Their conclusions were confirmed by Wigand who at a height of 9000 meters with about two-thirds of the mass of air under him found the last trace of the sun's spectrum at $\lambda = 2897$ the same as on the earth's surface. These results would indicate that the atmosphere must either possess a very steep absorption curve or that the absorbing medium is confined to the upper layers of the air.

The absorption of various gases and vapors is given in table 4. From a study of table 4 it appears as if the absorption of ultra violet light by air is mainly due to the presence of oxygen in the air

TABLE 4

Absorption of Ultra Violet Light by Gases and Vapors

GAS OR VAPOR	DEPTH	PER CENT ABSORBED	WAVE LENGTH ANGSTROM UNITS	AUTHORITY.
Air	0.05 mm.		< 1600	Schumann
	0.5 mm.	100.0	1630	Schumann
	9.1 mm.	100.0	1710	Lyman
	8–15.0 mm.	100.0	1780	Schumann
Dry air free from CO_2	20.45 cm.	8.8	1860	Kreusler
	20.45 cm.	Extremely small	1930	Kreusler
Oxygen	0.91 cm.	100.0	1760	Lyman
	20.45 cm.	32.5	1860	Kreusler
	20.45 cm.	6.2	1930	Kreusler
	20.45 cm.	Negligible	2000	Kreusler
Nitrogen	20.45 cm.	Very small	< 1620	Schumann
	20.45 cm.	2.2	1860	Kreusler
Carbon dioxide	0.91 cm.	100.0	1760	Lyman
	20.45 cm.	13.6	1860	Kreusler
Ozone		Negligible	In extreme ultra violet	Schumann
Helium	0.91 cm.	Not observable	1250	Lyman
Argon	0.91 cm.	Not observable	1250	Lyman
Hydrogen	0.91 cm.	Not observable	1250	Lyman
Water vapor in ordinary concentrations		Negligible	1900	Lyman

and that if necessary the source of light may be surrounded by hydrogen in order to lessen the absorption of the shortest waves emitted.

If we apply Lambert's law to the data relating to air, we obtain the figures in table 5.

Again, if the increased depth for each increase in wave length progressed as between λ = 1780 and λ = 1860, it would require

TABLE 5

Absorption of Ultra Violet Light by Air

DEPTH	PER CENT ABSORBED	WAVE LENGTH, ANGSTROM UNITS	INCREASED DEPTH PER 100 ANGSTROM UNIT INCREASE IN WAVE LENGTH	AUTHORITY
cm.			*cm.*	
0.05	100	1630		Schumann
0.91	100	1710	1.08	Lyman
1.50	100	1780	0.84	Schumann
232.40	100	1860	289.00	Kreusler

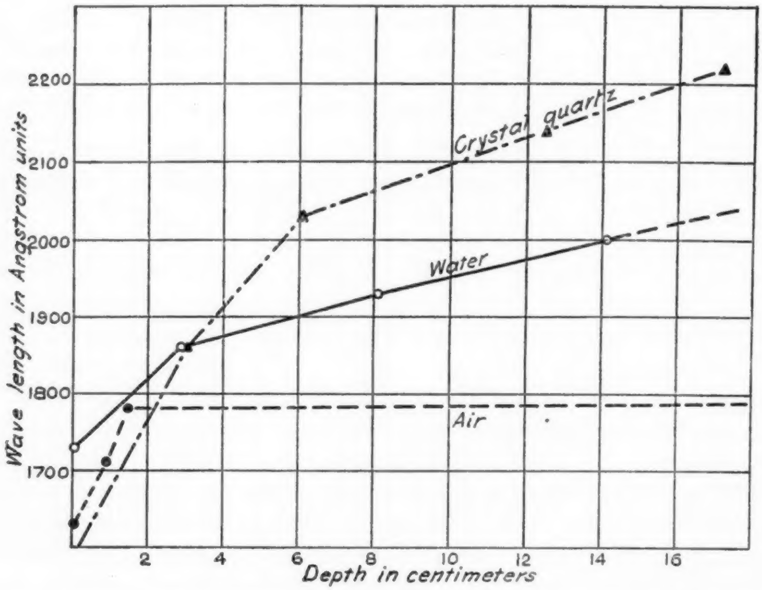


FIG. 1. ABSORPTION OF ULTRA VIOLET LIGHT OF DIFFERENT WAVE LENGTHS BY AIR, WATER AND QUARTZ

a column of air 3.5 meters deep to absorb all waves less than λ = 2000, and a column 28.9 meters deep to absorb those less than λ = 3000. The actual increase is very much greater, as substantiated by Wigand's experiments described above. For the purpose of

comparison the absorption values of air, water, and, in the absence of practical values for fused quartz, those for crystal quartz are plotted in figure 1.

Reflection of ultra violet light. We have seen that when a wave train falls upon a body capable of resonant vibration with it, the waves may be reflected instead of being absorbed, the amount of

TABLE 6

Reflection of ultra violet light by metals

DESCRIPTION	PER CENT OF RADIATIONS OF GIVEN WAVE LENGTH REFLECTED				TREND OF REFLECTION CURVE AT LAST POINT	AUTHORITY
	3800	2573	2510	2000		
Fresh silver mirror......	4 (3160)		34.1		Upward	Hagen and Rubens
Silver..................			25 (2500)	18 (2265)		Minor
Platinum...............			33.8	28 (probable)	Downward	Hagen and Rubens
Platinum...............		37.1				Meier
Gold....................	Approx. minimum		38.8		Upward	Hagen and Rubens
Gold....................		27.6				Meier
Copper.................	Approx. minimum		25.9		Slightly upward	Hagen and Rubens
Nickel..................			37.8		Downward	Hagen and Rubens
Nickel..................		30.7				Meier
Iron.....................			32.9		Downward	Hagen and Rubens
69 Al + 31 Mg..........	83		67		Downward	Hagen and Rubens
66 Cu + 22 Sn + 12 Zn.	60		40		Sharply downward	Hagen and Rubens
60 Cu + 30 Sn + 10 Ag.	60		40		Sharply downward	Hagen and Rubens
41 Cu + 26 Ni + 25 Sn + 8 Fe + 1 Sb........	50		35.8		Sharply downward	Hagen and Rubens
68.2 Cu + 31.8 Sn.......	56.4 (4000)		29.9 (2500)	18 (probable)		Minor
Wood's Alloy...........	56.6 (2747)	52.7				Meier

reflection varying with the composition and surface conditions of the object. The reflection of ultra violet light may be of value as there is no method of preventing the waste of a considerable amount of radiation in the application of this light to water disinfection. Up to the present time, however, no serious efforts have been made to utilize the reflecting power of metals. Table 6 has been prepared from Lyman's summary of past investigations.

The differences between Meier's values and those of Hagen and Rubens may be ascribed to surface conditions. Unfortunately there is no information relating to the reflection of wave lengths shorter than those listed above.

Ultra violet light emission spectra. The commercial application of ultra violet light to water sterilization is closely linked to the advances made in the study of the spectra of gases and solids with relation to their wealth in ultra violet radiations. We have seen that when light of an infinite number of colors is passed through a spectroscope the infinite number of overlapping images forms a continuous spectrum. If, however, only a finite number of colors is used, the images will not overlap and a discontinuous spectrum will be formed. When the body radiating energy consists of an incandescent solid or liquid, it appears to send out an infinite number of radiations and the spectrum formed is continuous, although not necessarily equally bright throughout. A gas or vapor, on the other hand, seems to emit only a few distinct lines of light producing a discontinuous or a line spectrum. When the gas or vapor is put under pressure and the temperature is increased, the lines are broadened into the bands of a discontinuous band spectrum. The electric spark between metallic electrodes gives lines due both to the terminals and to the surrounding atmosphere. When, however, a spark passes through a partially exhausted tube, the luminosity is confined to the gas and the metallic lines disappear. The spark and arc between metallic terminals were used as the first sources of ultra violet light. Finsen, for example, used the iron arc with great success. The development of water disinfection, however, was based upon the invention of the quartz mercury vapor electric lamp as a result of the discoveries of Way, Hewitt, and Kuch. In 1860 Way discovered the arc between mercury electrodes a source very rich in ultra violet light. The heat generated by the arc, however, evaporated the mercury. To prevent the escape of the vapors, Cooper Hewitt enclosed the arc in a glass vacuum tube and provided cooling chambers to permit the condensation of the vapor at the terminals. A glance at table 2 will show that glass does not permit the passage of the more refrangible rays and it remained for Kuch to enclose the arc in quartz, thus producing the quartz mercury vapor electric lamp, the present source of ultra violet light used for water disinfection. Since the arc is formed in vacuo, the metallic mercury evaporates and fills the tube under a pressure of approxi-

mately one atmosphere. The values for the mercury arc spectrum determined by Wolff are given in table 7.

The spectrum of the mercury arc is dominated by the great line at $\lambda = 1849.57$, which explains the fact that a short intimate contact with the light in a thin film accomplishes as much as a long exposure at a greater distance from the light. With a lamp made entirely of quartz, Lyman places the limit of its spectrum at 1774.9 Angstrom units. He ascribes this result to the absorption of the quartz and the absorption of the dense mercury vapor itself. It is, therefore, essential to keep the diameter of the luminous tube of the quartz lamp and the thickness of the envelope to a minimum. The absorption of the light by the mercury vapor itself explains the fact that the broad band at $\lambda = 1849.57$ is always strongly reversed;

TABLE 7

Emission Spectrum of Mercury Arc

WAVE LENGTH IN ANGSTROM UNITS	RELATIVE INTENSITY	WAVE LENGTH IN ANGSTROM UNITS	RELATIVE INTENSITY
1402.72	6	1849.57	>100
1435.63	2	1942.52	10
1650.17	8	1973.20	4
1672.75	5	1973.98	5
1675.55	4	1988.07	1
1774.95	5	2002.90	2
1832.60	4	2028.30	5
		2053.70	8

the width of the whole band is usually about 30 or 40 units and that of the reversed portion is about 6 units. This self reversion which results in a dark line within the band is ascribed to the circumstance that a vapor or gas will absorb those radiations which it can itself most readily emit. A study of figure 1 with a view of determining the maximum depth of water which can be reached by the great line at $\lambda = 1849.57$ shows that it is completely absorbed by approximately 2.5 centimeters of water or by 3.0 centimeters of quartz. The combined thickness of quartz and water must therefore not exceed approximately 2.5 centimeters, if this line is to be utilized. It does not necessarily follow, however, that an apparatus based upon these limits presents the only solution of the problem. If we consider the next line ($\lambda = 1942.52$), for example, we find that it is completely absorbed by only 9 centimeters of water and that the absorp-

tion of the quartz, which will seldom exceed 0.3 centimeter in thickness, is not more than 7 per cent. A proportionate increase in the time of exposure of water 8 centimeters in thickness may therefore equal a shorter exposure in thinner films. A similar method of reasoning may be applied to greater wave lengths, and explains why in practice considerable depths of water can be treated with good results.

Photoabiotic phenomena. The statement that sunlight is the cheapest and most common disinfectant has almost become a scientific platitude. The nature of the germicidal action of the sun's rays is, however, not equally well known. A critical study of the subject shows that the destructive power of the sun's spectrum does not begin until the blue-green, that it reaches a maximum in the blue-violet, and extends beyond. The disinfecting value of sunlight is, therefore, ascribed to the photoabiotic power of the waves of higher vibration frequency. The limit of the sun's spectrum on the earth's surface is soon reached at $\lambda = 2900$ and other sources of light are, therefore, used to determine the effect of rays of short wave lengths upon the living organism.

The mechanism of cell destruction. It is found that the destructive power of light increases in general with the vibration frequency from the visible into the extreme ultra violet, where it is limited (at $\lambda = 1600$ approximately) by the fact that light of shorter wave lengths cannot penetrate sufficiently far into the living cell to materially affect its life processes. The photoabiotic action of ultra violet light furthermore seems to follow very closely Talbot's photochemical law that the amount of chemical change effected is proportional to the product of the intensity of the light and the length of exposure. It differs from this law only in that, when the exposure is interupted, the chemical changes produced in each exposure are additive while the photoabiotic changes are so only when the time elapsing between exposures is not sufficiently great to permit the organism to exert its power of repair. It is found that the rate of recovery from ultra violet radiation follows approximately the "die-away" curve, so that the percentage increase in the number of recovering organism is constant for each unit interval of time elapsing between exposures. The statement is often made that ultra violet radiations produce cytolysis through the absorption by the organism of a toxin produced photochemically in the surrounding medium rather than through direct action upon the living cell.

Experiments, however, have shown that, for example, the amount of hydrogen peroxide, which is claimed to be the destructive agent in the disinfection of water by this method and which is formed in water exposed to ultra violet light, is not sufficient to produce cytolysis. On the other hand, it can be shown that when a number of organisms are suspended in the same medium and only a few of them are exposed to the rays the latter alone will be cytolized, while those protected from ultra violet radiations, either by being out of the cone of light or by being protected by a small piece of suspended matter, remain unharmed. This would be impossible if the lethal agent were produced in the medium and not in the organism itself.

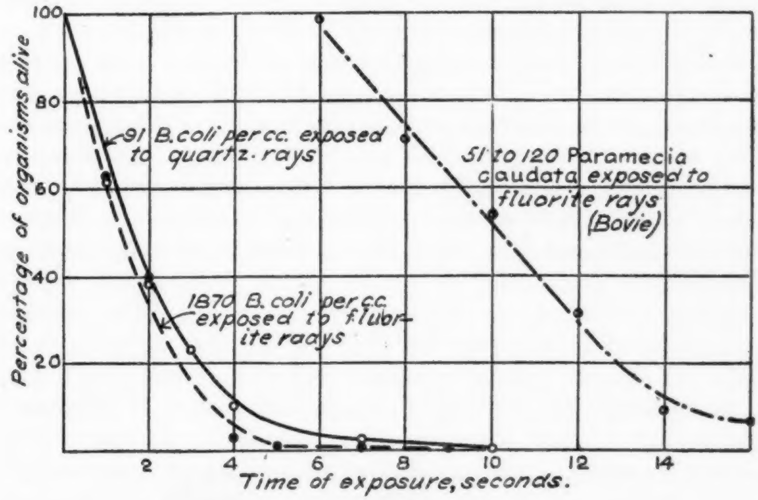


Fig. 2. Death Curve of Organisms Exposed to Ultra Violet Light

The curve of disinfection illustrated in figure 2 suggests, however, that the mode of death through exposure to high frequency vibrations is similar to that through poisons, heat, or drying. The exact shape of the curve depends upon the resistance of the individual organisms and their position in the medium exposed to the light. The initial lag in the "die-away" curve of the larger paramecia obtained by Bovie is to be expected. It is noteworthy that the number of cells dying in a given time interval is approximately proportional to the number of cells surviving; that, therefore, the rate of disinfection within practical limits is independent of the number of organisms present. The steepness of the curve is greatly

influenced by the method of exposure. If the medium in which the organisms are suspended is stirred constantly, the chance of direct radiation is increased and the slope of the resulting curve of disinfection is very much greater. This fact explains the advantage of designing apparatus in such a manner as to maintain a vigorous stirring of the water which is to be disinfected.

The exact mechanism of cell destruction is by no means thoroughly understood. We know, however, that the rays must be absorbed in order to produce cytolysis and that seemingly the action is due to accelerated catabolism which, if exposure is continued, causes the death of the organism within a short space of time, after which photochemical processes seem to complete the destruction and dissolution of the cytoplasm. This theory is substantiated by the departure of the photoabiotic action of the rays from Talbot's photochemical laws in that an organism which has not been exposed too long may recover from the destructive effects of the rays and in some cases resume its normal life process of growth and reproduction.

After growths. The disinfection of water supplies and swimming pools by chemicals sometimes leads to a rapid increase in the number of those organisms which, due to some cause or other, escape destruction. In the clear field presented for growth, they multiply rapidly and may even exceed the bacterial count obtained before disinfection. Several factors may influence the survival of these living cells: (1) naturally greater resistance and spore formation; (2) protection afforded by particles of foreign matter; and (3) incomplete disinfection. Except under the second condition, the use of ultra violet light seems to present a distinct advantage over other methods of disinfection. It is claimed that, due to greater transparency, spores are more easily killed by light than vegetative forms, which accounts for the fact that enormous numbers of B. subtilis, which organism in the microscopic world is the counterpart of the proverbial nine-lived cat, are readily destroyed by quartz rays. The effect of incomplete disinfection by ultra violet light is illustrated in figure 3.

A consideration of the results obtained with wave lengths of $\lambda = 2800$ leads Bovie to the following conclusions: (1) the length of exposure required for inhibition is only about one-thirtieth of that required to produce cytolysis; (2) the duration of the inhibition increases with increased exposure; and (3) the inhibition is followed by an acceleration in reproduction. A study of the rate of repro-

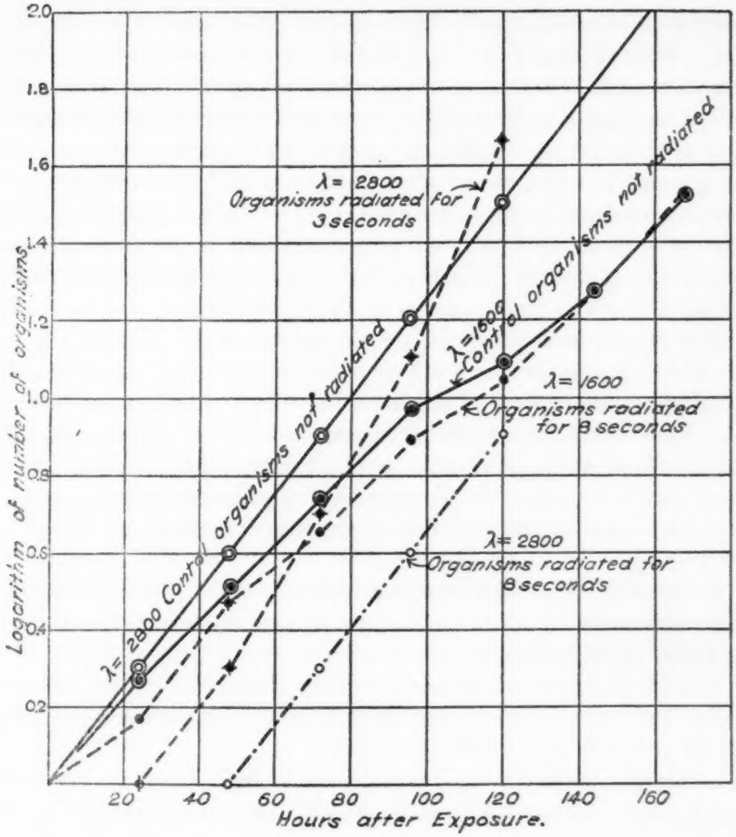


FIG. 3. EFFECT OF ULTRA VIOLET LIGHT OF DIFFERENT WAVE LENGTHS ($\lambda = 1600$; $\lambda = 2800$) UPON THE RATE OF DIVISION OF PARAMECIUM CAUDATUM (AFTER BOVIE)

TABLE 8

Aftergrowths of B. Coli Exposed to Quartz Radiations

SAMPLE NUMBER	TIME OF EXPOSURE	ORGANISMS PER CUBIC CENTIMETER			REPRODUCTION FACTOR
		Before radiation	After radiation	After incubation for 48 hours at 37°C.	
	seconds				
1	0	42	42	10,100	7.91
2	2	42	24	1,080	5.49
3	4	42	11	128	3.54

duction of organisms surviving radiations of $\lambda = 1600$, on the other hand, suggests that these rays, although more destructive in a given length of time, are unable to penetrate to the nucleus of the cell in the same degree as light of longer wave lengths and that reproduction is therefore not inhibited except when the organism is killed. As a result of these observations, a source of light emitting rays of varying frequency suggests itself as the best disinfecting agent. This is further substantiated by experiments made under the author's direction with B. coli in water to which a small amount of nutrient broth had been added as shown in table 8.

The figures in the last column were obtained by assuming a geometrical increase in the number of organisms and calculating the number of generations or cell divisions which would have occurred had each surviving organism reproduced at the same rate. The number and type of organisms developing after disinfection depend naturally upon the composition of the surrounding medium and vary with waters of different physical, chemical, and biological content.

Summary. The most important points of the theory underlying the application of ultra violet light to water sterilization may be summed up as follows:

1. The photoabiotic properties of light are due to the action of high frequency vibrations extending from the blue-green ($\lambda = 4800$) to the extreme ultra violet ($\lambda = 1600$).

2. Matter decreases in transparency to light from the visible to the extreme ultra violet as the wave lengths decrease until even highly rarified gases are opaque.

3. Fused quartz is at present the solid most readily adapted for use with ultra violet radiations. It permits the passage of light of wave lengths as small as $\lambda = 1800$, melts at about 1700°C., has a linear coefficient of expansion of 0.39×10^{-6} centimeter per degree Centigrade per centimeter, and is obtained pure in large quantities.

4. Water is transparent to a considerable depth and can therefore be disinfected by the radiations emitted by a quartz mercury vapor electric lamp.

5. The absorption of ultra violet light by air is due to its oxygen content but is not sufficiently great to be of consideration outside of the laboratory.

6. The reflection of ultra violet light by metals warrants a greater effort for its utilization.

7. The quartz mercury vapor electric lamp emits radiations as small as 1800 Angstrom units in wave length. It is, therefore, possible to utilize the great line at $\lambda = 1850$ for short exposures and intimate contacts while making use of the rays of smaller vibration frequency for longer exposures at greater distances.

8. The destructive power of light begins in the blue-green ($\lambda = 4800$) and increases with the vibration frequency up to $\lambda = 1600$ approximately.

9. Talbot's photochemical law, if correctly interpreted, is applicable to photoabiotic phenomena.

10. The rate of recovery from ultra violet radiations follows approximately the "die-away" curve.

11. High frequency vibrations of light act directly upon the organism and not indirectly through the medium.

12. The mode of disinfection through light, poisons, heat, and desiccation is very similar.

13. The destruction of the cell is due to increased catabolic changes.

14. Aftergrowths are limited by the inhibition of organisms surviving exposure to ultra violet rays.

15. Light of short wave lengths ($\lambda = 1600$) is more effective in destroying organisms but less effective in decreasing the rate of reproduction of those organisms which are not killed by exposure.

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METHODS OF RELIEVING THE WATER SHORTAGE IN BALTIMORE[1]

The water supply conditions in Baltimore are complicated by a shortage of water for the population within the old city limits and by the necessity of establishing a policy for the water supply of a large suburban district, now served by nine private companies, which was recently annexed to the city.

More water must be provided for the old city territory as quickly as practicable. In 1918 and 1919, the average daily consumption was about 110,000,000 gallons. The maximum consumption for a single day sometimes reached 154,000,000 gallons, and the average daily consumption during the month of greatest demand was 121,000,000 gallons. The months of greatest demand usually occur in seasons of drought, when the available supply is very low. Under the present operating conditions, as will be explained later, there is practically no available storage in the Loch Raven reservoir, where the Gunpowder River is impounded to furnish a supply, and the average flow of this river during a dry month has fallen to 54,000,000 gallons a day. In an emergency the city can obtain water from Jones Falls, but in very dry weather not much more than 6,000,000 gallons a day will probably be available from this source.

The capacity of the eight reservoirs within the city is 1,200,000,000 gallons. During periods of drought, when Gunpowder River and Jones Falls may furnish only 60,000,000 gallons a day, the result of a continued average daily consumption of 110,000,000 gallons will be to exhaust the stored supply in 24 days, leaving the city with but half the daily supply it now requires. This will happen when the demand is usually greater than the average for the year.

Some relief can be obtained by reducing the waste of water in the city. The consumption is now about 180 gallons per capita daily. It is highly desirable to start a water waste survey at once

[1] Review by the Editor of a report to William F. Broening, Mayor of Baltimore, by Nicholas S. Hill, Jr., Consulting Engineer, New York, and James H. Fuertes, Consulting Engineer, New York.

and metering should be carried on as rapidly as possible to prevent the outlay of unnecessary sums for enlargements of the water system which will benefit nobody. In this way, perhaps as much as 20,000,000 gallons of water now wasted daily can be saved.

To meet the present situation, there are four possible developments of additional supplies. The water for the old city is impounded at Loch Raven dam, which has its spillway at El. 188. Tipping gates[2] have been placed on the spillway which raise the water level to El. 192, but these gates open when the water rises above that elevation so that the permanent effective high water level at Loch Raven is El. 188. The catchment area above the dam is 308 square miles.

The water flows from Loch Raven to a pumping station at Montebello through a tunnel 12 feet in diameter and 7 miles long. This tunnel is not lined throughout and there is some question whether it will be possible to increase the head on the tunnel by any substantial amount without causing serious leakage from the tunnel, unless the portions now unlined are lined.

At Montebello the water is lifted from the tunnel by pumps to a filtration plant, from which it flows by gravity to the low-service district of the city. In the city there are three pumping stations supplying intermediate and high-service distribution systems.

The center line of the Montebello pumps is at El. 199.25, and as it is unsafe to count on a suction lift of more than 21 feet, the lowest safe water level in the tunnel at the pumping station, under the existing conditions, is 199.25–21 or El. 178.25. The present maximum operating head is, therefore, 188–178.25 or 9.75 feet. Actual measurements show that when water is flowing through the tunnel at the rate of 154,000,000 gallons daily, the friction head is 9.75 feet. It will be seen that the maximum safe capacity of the tunnel under present operating conditions does not exceed the present maximum daily consumption.

There is another serious aspect of the present conditions. There is not sufficient water stored for distribution in the small reservoirs in and near the city to equalize the fluctuations in the demand on the filtration plant. The latter must be operated at varying rates in order to meet these fluctuations. In time of maximum demand, in order to obtain the necessary quantity of water, the full head of

[2] See JOURNAL, June, 1919, page 297.

9.75 feet on the tunnel is necessary, and this can only be obtained by keeping the water at Loch Raven dam at the elevation of the spillway and giving up all attempts to consider the storage at Loch Raven, under existing conditions, as available for use at any time. The additional storage created by the tipping dam may be available, but it is not certain.

In order to obtain an ample supply for present needs and the demands of the near future in the old city of Baltimore, water can be obtained by further developing the Gunpowder watershed or by utilizing the Patapsco River watershed. These developments must be accompanied by an increase in the capacity of the filtration plant, the construction of new distributing reservoirs and a new high-service pumping station, and improvements in the system of distribution mains. There are four of these projects which have enough merit to be considered in detail.

In developing the Gunpowder River supply, it is necessary to increase the quantity of water stored and to provide means for bringing more water to the Montebello filters than the existing tunnel will deliver under the present operating conditions.

There are two methods of obtaining more storage on the Gunpowder River. One is to raise the Loch Raven dam and the other is to construct one or more additional reservoirs on the watershed. The dam was designed and its foundations constructed so that the spillway can be placed at El. 240. If any attempt is made to place the spillway higher than that the cost of the work will be greatly increased by the necessity of relocating a considerable mileage of railroad and by damages due to flooding a portion of the village of Cockeysville. Additional storage can also be obtained by building a dam on the Gunpowder River about 3 miles from Parkton, called the Prettyboy dam. If its spillway is placed at El. 520, about 24,000,000,000 gallons will be impounded, which can be allowed to flow down the river to the Loch Raven reservoir as needed there.

There are two methods of bringing more water from Loch Raven to the Montebello filters; one is to build a new tunnel and the other is to utilize the old tunnel to better advantage than is practicable under existing conditions.

The better utilization of the present tunnel is made possible by the existence near the filtration plant of Lake Montebello which, when full, has its water level at El. 163, 15.25 feet lower than the

minimum permissible elevation of water in the tunnel at the present pumping station at Montebello. This water may be discharged from the tunnel into the lake, and by building a new low-lift pumping station at the lake, the water can be delivered from it to the filtration plant. The lake will thus serve as an equalizing basin, materially reducing the present fluctuations in the velocity through the old tunnel and enabling the average discharge to approach more nearly to the full capacity of the tunnel than is now safe. With the spillway at Loch Raven at El. 240, there will be about 22,000,000,000 gallons storage at that place, and this water can be delivered to Lake Montebello under an effective head of 23 feet, if desired. Under this head the old tunnel will deliver 240,000,000 gallons daily, and by regulating the gates at Loch Raven this quantity can be reduced as desired.

The Patapsco River can be utilized by taking advantage of the present development of that stream by the Baltimore County Water & Electric Company at Avalon. The catchment area above this point is 321 square miles. An intake, pumping station and filtration plant must be built there, from which water can be pumped into the city's low-service distribution system or into both the low and intermediate systems. The flow of the river at Avalon during the driest months is probably about 54,000,000 gallons daily, and if a plant is built for this development it will be desirable for it to have a capacity of 50,000,000 gallons daily.

In addition to increasing the quantity of water available for the old city of Baltimore it is necessary to enlarge the capacity of the Montebello filters if the increased supply comes from the Gunpowder watershed, construct a distributing reservoir near the southwestern boundary of the city to equalize the effect of the large fluctuations in the hourly consumption in the low-service district on the filtration plant whether it be solely at Montebello or partly there and partly at Avalon, to modify the distribution system so that the storage in the existing distributing reservoirs will also help in steadying the load on the filters, and to construct two new high-service distributing reservoirs with a pumping station and improvements in the mains. If such equalizing storage is provided, the additional filtration capacity required is not over 52,000,000 gallons daily. If the storage is not provided the additional filters should have a capacity of at least 100,000,000 gallons daily. The four most desirable projects for improving the supply of the old city include the equalizing storage facilities just mentioned.

Project 1. Raise Loch Raven dam to El. 240, build a new 12-foot tunnel 7 miles long from Loch Raven to Montebello, construct the Prettyboy reservoir, abandon the Montebello pumps and operate the filters by gravity, add filtration capacity of 52,000,000 gallons daily and construct equalizing storage works on the distribution system. The total first cost is estimated at $20,853,000, giving an annual cost of $1,065,300 and making the annual cost per million gallons of capacity $18.53. This is the most expensive project and will take the most time to construct. The watershed above the Prettyboy reservoir is not large enough to prevent protracted low stages of the water in that basin, with heavy growths of vegetation on the exposed bottom. This project is not recommended.

Project 2. Raise Loch Raven dam to El. 240, build a new 12-foot tunnel 7 miles long from Loch Raven to Montebello, enlarge the present Montebello pumping station, pump from the tunnel to the filters when the water in Loch Raven reservoir is below El. 230.5 and deliver it by gravity at other times, add 52,000,000 gallons to the daily filtration capacity, and construct equalizing works on the distribution system. This project calls for a capital outlay of $17,457,000 and the annual charge will be $912,400. The annual cost per million gallons of capacity will be $17.66. This project will take longer to construct and cost more than Project 3 and is not recommended.

Project 3. Raise Loch Raven dam to El. 240, deliver water through the present tunnel to Lake Montebello, abandon the present pumping station there and erect a new 185,000,000-gallon station to pump from the lake to the filtration plant, add 52,000,000 gallons daily to the filtration capacity, and construct equalizing storage works on the distribution system. The capital outlay for this project is $13,994,000 and the annual charge will be $899,150. The annual cost per million gallons of capacity will be $17.41. This is the cheapest in first cost of the plans for obtaining water from the Gunpowder River and can be carried out most quickly.

Project 4. Take water from the Patapsco River at Avalon, construct a 50,000,000 gallon filtration plant and high-lift pumping station there, and construct equalizing storage works on the distribution system. The first cost will be $9,642,000 and the annual cost $775,150. The annual cost per million gallons of capacity will be $19.70. This is the cheapest in first cost and the annual cost per million gallons of capacity is reasonable, but as the avail-

ble supply from this source is insufficient to meet present needs it cannot be considered alone.

The immediate undertaking of Project 3 is recommended, but the adoption of Project 4 is also advised in order to secure enough water for the next twenty years. The Patapsco supply may be quickly developed at reasonable cost, it will be delivered to the city in a way which will help equalize pressures in a large part of

FIG. 1. LIMITS OF THE OLD CITY OF BALTIMORE, OF THE ANNEXED TERRITORY, AND OF THE AREAS SERVED BY PRIVATE WATER COMPANIES.

1. Baltimore County Water & Electric Company's Territory. 2. Roland Park Water Company's Territory. 3. Brooklyn & Curtis Bay Light & Water Company's Territory. 4. Dundalk Water Company's Territory. 5. Suburban Water Company's Territory. 6. Artesian Water Company's Territory. 7. Evergreen Lawn Water Company's Territory. 8. Rognel Heights Water Company's Territory. 9. Denmore Park Hotel, Water, Light & Heating Company's Territory.

the city, and will cost no more than the development of 50,000,000 gallons from the Gunpowder basin in addition to the quantity provided under Project 3.

What has been said up to this point applies only to the old city of Baltimore. The water supply of the recently annexed districts presents troublesome technical, financial and administrative problems. There are nine private companies which are furnishing about 7,000,000 gallons daily to from 70,000 to 75,000 persons in this Annex, as the territory is called. The Baltimore County Water & Electric Company is the largest of these and supplies about 5,600,000 gallons daily; it also furnishes water to a large number of consumers outside the city. It is the only company which was not primarily part of a real estate development. There is no possibility of increasing the output of the eight small companies except for temporary local use. One of them supplies only 150 houses in the city and another supplies a small area outside the city. Before the city can extend its water mains into any territory occupied by the nine private companies, shown in figure 1, it must acquire by purchase or condemnation their property in the territory the city proposes to enter.

On January 1, 1920, the valuation of these properties, based on the cost of reproduction, was estimated at \$3,900,000 by the engineers and \$5,543,000 by the companies. The annual cost of operating the pumping stations and maintaining the sources of supply of the companies is estimated at \$100,000 to \$125,000.

The total capitalization of the Baltimore County Water & Electric Company is \$1,283,000; the valuation of its property based on the cost of reproduction is estimated at \$2,723,000 by the engineers and \$3,819,000 by the company. The supply is obtained from the Patapsco River at Avalon, west of the city, and from Herring Run to the east of the city, and the company owns water rights on the Little Gunpowder River near Bradshaw. The Herring Run supply is of inferior quality and small quantity, and the company has been advised to abandon it and to supply the district now served with Herring Run water from a new plant to be built on the Little Gunpowder, which has a catchment area of 57.5 square miles above Bradshaw.

If the city acquires the plants of the private companies a heavy expenditure will be needed for their rehabilitation and a large sum must be spent for connecting the city mains to those of the com-

panies. All told, if the city takes over the plants, it will probably have to spend about $5,500,000 for the works, franchises, rehabilitation, connections and operation until water can be furnished from the new city supply. In addition it must either furnish water during the period of reconstruction to the old consumers in the Annex at the present rates, which have been approved by the Maryland Public Service Commission, or else reduce the rates to those now charged in the old city of Baltimore, which do not equal the cost of furnishing the water, the deficit being met by a contribution from the general taxes.

It is apparent that the acquisition of the private plants will be expensive, that with the same rates now charged in the old city they will not yield a sufficient return to pay for the investment in them, and that the only valuable additional supply secured with them is the Patapsco River. Therefore there is no strictly economic justification for their purchase. There are other reasons, however, which render the purchase advisable.

Some of these private supplies are of poor quality, and an outbreak of typhoid fever or other intestinal disease due to the infection of one of them may result in the spread of the disease by contact among the consumers of other water supplies.

As an administrative policy, it will be undesirable to allow private companies to operate within the city for a long period without an adjustment of rates so that all consumers within the city will pay the same rates. The Maryland Public Service Commission and not the city establishes the rates of private companies. These are fixed so that the companies may earn a fair return upon a fair valuation of their property. These rates are necessarily higher than those of the city. Unless the city can make an arrangement with the private companies whereby they will charge the same rates as the city and the city will undertake to make up the deficiency in their earnings as a result of this reduction, those residents of Baltimore supplied by the private companies must not only pay much higher water rates but must also, through their general taxes, help pay the cost of furnishing water to the consumers supplied by the municipal water works. One-seventh of the population of the city will not be content to suffer such discrimination long.

There are other reasons for acquiring these private water works. If the companies remain in existence there will be trouble between them and the city over extensions into territory now without water

mains. The probability that the city will acquire the properties at some time will check their development by the companies, and as the service deteriorates there will be an increasing number of complaints which will inevitably lead to the purchase of the properties by the city

Under all the circumstances, it is advisable to acquire these plants and apply to the legislature for authority to supply water in the immediate suburbs of the city. All future extensions of mains in this suburban district will then be under the direction of the municipal water department, in accordance with its plans and specifications. When the city boundaries are pushed backward again, as they have already been pushed back on two occasions, it will not be necessary to spend large sums for buying and rehabilitating water works unsuited for the future needs of the city.

The total capital outlay recommended for new supplies, purchase of private water plants, and the improvement of existing works is $21,785,000.

AN INQUIRY INTO THE EFFECT OF METEOROLOGICAL CONDITIONS UPON THE EFFICIENCY OF STORAGE, FILTRATION, AND CHLORINATION, BASED UPON A STUDY OF THE HAGERSTOWN WATER SUPPLY[1]

By Abel Wolman[2]

For several years past the quality of the Hagerstown, Md., water supply has been the source of considerable discussion, on account of the wide fluctuations in daily physical and hygienic quality. The various attempts to obviate these difficulties by increases in chlorine dosage up to excessive points have not served to eliminate, in any appreciable degree, the sudden and recurrent rises in bacterial content. In view of this state of affairs, a detailed study of the Hagerstown water supply situation, with particular reference to the cause of its varying sanitary condition, has been carried out. The results of this study are set forth below.

Hagerstown obtains its water during most seasons of the year from Warner Gap Hollow and Raven Rock Hollow, two small streams located on South Mountain. The drainage area of Warner Gap Hollow is 2.65 and that of Raven Rock Hollow 3.20 square miles, a total of 5.85 square miles. No storage is provided in Raven Rock Hollow but all the water, except during times of high flow, is diverted into a pipe line and run into Edgemont Reservoir, which is located in Warner Gap Hollow and has a capacity of 95,000,000 gallons. The inlet is located within a short distance of the outlet of Edgemont Reservoir, as shown in figure 1. From Edgemont Reservoir the water is delivered through a 12-inch cast iron and a 16-inch wood stave pipe to a reservoir of 20,000,000 gallons capacity located at Smithsburg. The water leaving this reservoir is treated with liquid chlorine and is brought to Hagerstown through two cast iron pipes, 12 inches and 16 inches in diameter respectively.

[1] Prepared for eventual publication in an engineering bulletin to be issued by the Bureau of Sanitary Engineering of the Maryland State Department of Health. Discussion is requested and should be sent to the Editor.

[2] Division Engineer, Maryland State Department of Health, Baltimore, Md.

The drainage areas of the streams in Warner Gap and Raven Rock Hollows, while of mountainous character, support more or less population. Thorough sanitary surveys of these drainage areas have been made by the Maryland State Department of Health and numerous nuisances have been corrected. The water company now maintains a regular patrol.

Whenever the amount of water obtainable from South Mountain is not sufficient to supply Hagerstown the water company puts into operation a rapid sand filtration plant which was constructed some years ago at Bridgeport. Water for supplying this plant is taken from Antietam Creek at this point, is filtered and disinfected but not softened, and is then pumped to Hagerstown through the existing 12-inch and 16-inch pipe lines running from South Mountain.

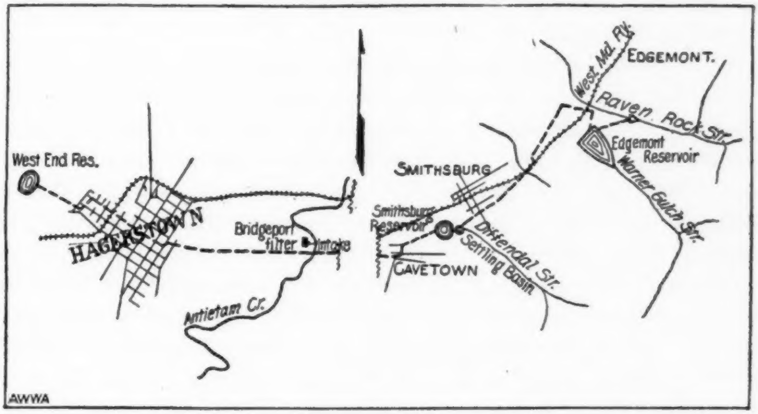


Fig. 1. Sources of Hagerstown Water Supply

The usual method followed in supplying Hagerstown with water is to use the South Mountain source as long as water is available in the Edgemont Reservoir; when the water in this reservoir has been drawn down to a low point the Bridgeport filtration plant is started and is then operated until rains replenish the reservoir. The period during which the filtration plant is operated varies from year to year as weather conditions make necessary.

The quality of the tap water has not been sufficiently good in past years and has been the subject of study by the State Department of Health. Robert B. Morse, Chief Engineer of the Department, has recommended in past years the relocation of the Raven Rock intake, so as to permit the water to enter the Edgemont

Reservoir at its head, the construction of a settling and coagulating basin at Smithsburg, to make more effective the intermittent application of alum to the mountain supply, and methods of operation of the Bridgeport filtration plant.

These improvements have not yet been completed but their necessity is made apparent by the confirmatory analytical data here discussed.*

In order to make a complete study of the water supply of a city in which the source of water is subject to considerable fluctuations in physical and hygienic quality, it is essential to have available a long and continuous series of analytical results. In the absence of such an extended series, it is not only impossible to measure accurately the variations in daily quality, but it becomes difficult to predict with certainty just what modifications will eliminate future objectionable conditions.

In Hagerstown, fortunately, we have at hand a complete history of the tap water for the period from February 11 to September 30, 1918, based upon examinations made by the city's analyst. The period since February 11 is used in this study because it is only since that date that the analyses have followed closely and consistently a standard procedure. These are used in place of the routine State determinations on account of their greater frequency and because they are not subject to the varying effects resulting from delays in transportation. They afford the only reliable continuous daily record of Hagerstown tap water quality now available.

The purpose of the present study is not only to analyze the past quality of the water, but to endeavor to obtain from present sources of information the possible causative factors of such fluctuations in the water as have occurred. This attempt is directed, therefore, more towards determining the causes of *variation* in, than towards grading, the quality of the tap water, It is apparent that, if such a study is successful in determining the causes of fluctuation in quality, the elimination of such causes becomes a matter of practical readjustment, with a necessary consequent improvement in general quality.

The unit of measure which is to serve as the index in this study will be the number of B. coli per 100 cc. found, either by presumptive or isolation test, in the tap water each day. The evaluation of

* Certain recent extensions at Bridgeport make the operation of the filtration plant more satisfactory.

TABLE 1

Elevation of water in inches above or below the spillway of Edgemont Reservoir, rainfall in inches per day at Chewsville, and B. coli in 100 cc. in tap water, during part of 1918

February	10	11	12	13	14	15	16	17	18	19
Reservoir elev.	−374	−350	−312	−228	−144	−72	+6	+5	+4	+4
Rainfall		T.			0.06	*			†	‡
B. coli, presump.	2	2	5	15	35				9	5
B. coli, isolation	0	0	5	15	35				9	5
February	§20	21	22	23	24	25	26	27	28	*M.* 1
Reservoir elev.	+7	+5	+4	+4	+4	+4	+4	+4	+4	+4
Rainfall	0.65		0.05			T.	0.46		¶	
B. coli, presump.	5	2	0	5		2	5	5	5	9
B. coli, isolation	5	2	0	0		2	0	0	5	0
March	2	3	4	5	6	7	8	9	10	11
Reservoir elev.	+4	+3	+3	+2	+2	+2	+2	+2	+3	+2
Rainfall			‡	0.40	T.			0.29	T.	
B. coli, presump.	2		9	2	5	2	5	5		5
B. coli, isolation	0		9	0	0	0	2	0		0
March	12	13	14	15	16	17	18	19	20	21
Reservoir elev.	+2	+2	+3	+3	+2	+2	+2	+2	+2	+2
Rainfall	0.04	1.05	0.63							T.
B. coli, presump.	2	5	5	2	2		2	2	2	2
B. coli, isolation	0	2	2	0	0		0	0	2	0
March	22	23	24	25	26	27	28	29	**30	31
Reservoir elev.	+1	+1	+1	+1	+1	+1	+1	+1	0	−1
Rainfall										
B. coli, presump.	5	5		2	2	2	5	2	5	
B. coli, isolation	2	2		0	0	0	2	0	2	
April	1	2	3	4	5	6	7	8	9	10
Reservoir elev.	−3	−4	−4	−5	−7	−9	−12	−15	−10	+12
Rainfall	T.		0.04					0.40	0.90	1.75
B. coli, presump.	2	9	5	2	2	5		2	5	2
B. coli, isolation	0	5	2	0	0	2		0	5	2
April	§11	12	13	14	15	16	17	18	19	20*
Reservoir elev.	+7	+6	+5	+3	+4	+7	+6	+4	+3	+3
Rainfall	0.70	0.34	0.15							0.32
B. coli, presump.	2	2	5		2	0	2	5	2	2
B. coli, isolation	0	2	0		0	0	0	2	2	0
April	21	22	23	24	25	26	27	28	29	30
Reservoir elev.	+8	+6	+4	+3	+2	+2	+2	+1	+1	0
Rainfall	1.06		0.03	0.03	0.40				0.06	
B. coli, presump.		2	5	5	5	2	2		2	5
B. coli, isolation		0	2	0	0	2	2		0	5
May	**1	2	3	4	5	6	7	8	9	10
Reservoir elev.	+3	+3	+3	+3	+3	+3	+3	+3	+2	+2
Rainfall	0.25			0.03				0.11		0.14
B. coli, presump.	5	2	2	5		2	5	2	5	9
B. coli, isolation	5	0	0	2		0	2	0	5	2

* February 12–18; heavy runoff from watershed.

† February 18–20; temperature below freezing.

‡ Precipitation included in the next following measurements.

§ Raven Rock stream cut off.

¶ Water from Edgemont Reservoir turbid.

** Raven Rock stream turned on.

TABLE 1—*Continued*

May..................	11	12	13	14	15	16	17	18	19	20
Reservoir elev......	+2	+1	+1	+2	+2	+1	+1	+1	0	−1
Rainfall............			0.20	0.20						
B. coli, presump....	5		9	9	5	5	5	2		9
B. coli, isolation....	2		5	9	2	2	2	0		5
May..................	21	22	23	24	25	26	27	28	29	30
Reservoir elev......	−3	+4	+3	+2	+1	+1	0	−1	−2	−3
Rainfall............	0.45		0.52						0.26	0.12
B. coli, presump....	20	9	5	5	9		9	5	12	9
B. coli, isolation....	12	5	2	2	9		5	2	8	2
June..................	*M.* 31	1	2	3	††4	5	6	7	8	9
Reservoir elev......	−4	−5	−7	−9	−12	−15	−18	−22	−27	−33
Rainfall............	0.65							0.25		
B. coli, presump....	5	5		5	9	5	5	2	5	
B. coli, isolation....	2	2		5	9	2	2	0	0	
June..................	10	11	‡‡12	13	14	15	16	17	18	19
Reservoir elev......	−39	−46	−53	−61	−70	−80	−91	−100	−108	−116
Rainfall............		0.09			0.09				T.	
B. coli, presump....	9	5	5	5	5	2		2	5	2
B. coli, isolation....	5	2	2	0	2	0		0	0	0
June..................	20	21	22	23	24	25	26	27	§§28	29
Reservoir elev......	−124	−132	−126	−129	−135	−142	−149	−166	−165	−174
Rainfall............		0.15	0.59	T.		0.01	0.03			0.03
B. coli, presump....	2	0	2		2	0	2	5	5	
B. coli, isolation....	0	0	2		0	0	2	2	5	
July..................	*J.* 30	1	2	3	4	5	6	7	8	9
Reservoir elev......	−178	−186	−196	−207	−218	−230	−242	−256	−271	−287
Rainfall............	0.65					0.27	T.			
B. coli. presump....		9	20	9	5	5	5		5	2
B. coli. isolation....		5	12	9	2	2	2		2	0
July..................	10	11	12	13	14	‡‡15	16	17	18	19
Reservoir elev......	−305	−323	−341	−359	−373	−407				
Rainfall............		0.23	T.	0.50	0.14			0.08		0.39
B. coli. presump....	5	2	2	2		5	5	2	5	9
B. coli. isolation....	2	0	0	2		0	2	0	0	5
July..................	20	21	¶¶22	23	24	25	26	27	28	29
Reservoir elev......										
Rainfall............					0.66	0.91				
B. coli. presump....	12		5	2	5	231	2454+	231		12
B. coli. isolation....	12		2	0	2	231	2454+	231		12
August...............	*J.* 30	*J.* 31	1	2	3	4	5	§§6	7	¶¶8
Reservoir elev......		−468								
Rainfall............	0.38	T.				T.	0.80		0.04	0.06
B. coli. presump....	5	5	5	5	5		5	2454+	2454+	231
B. coli. isolation....	5	2	5	2	2		2	2454+	2454+	231

†† Alum dosage started at Smithsburg.

‡‡ June 12–27 and July 15–20; Antietam Creek partly used.

§§ June 28– July 13 and August 6–7; all mountain supply.

¶¶ Antietam Creek entirely used, July 22–August 5, and practically so August 8–30.

TABLE 1—*Concluded*

August	9	10	11	12	13	14	15	16	17	18
Rainfall	0.18	0.05		0.50	0.12	T.	0.07		T.	0.02
B. coli. presump.	231	2454+		2454+	231	231	231	12	9	
B. coli. isolation	231	2454+		2454+	231	231	231	12	5	
August	19	20	21	22	23	24	25	26	27	28
Rainfall							1.49	T.	0.05	0.15
B. coli. presump.	9	5	2	2	5	5		2454+	2454+	231
B. coli. isolation	5	2	0	0	0	2		2454+	2454+	231
September	*A.* 29	*A.* 30	*A.* 31	1	2	3	4	5	6	7
Rainfall	0.07	0.23	0.07			T.		0.76	0.35	
B. coli. presump.	5	2	5		2454+	231	12	8	231	12
B. coli. isolation	2	0	2		2454+	231	5	5	231	9
September	8	9	10	11	12	13	14	15	16	17
Rainfall	0.14			0.10	T.	0.05			0.01	0.03
B. coli. presump.		20	9	5	2	2	2		3	2
B. coli. isolation		9	5	2	0	0	0		2	0
September	18	19	20	21	22	23	24	25	26	27
Rainfall	0.64		0.95	0.13					T.	
B. coli. presump.	3	2	231	231		12	2	2	0	5
B. coli. isolation	2	2	231	231		9	2	0	0	0
September	28	29	30							
Rainfall										
B. coli. presump.	2		5							
B. coli. isolation	0		2							

these numbers from the qualitative results furnished by the data has been carried out by the McCrady method. The description of this method is irrelevant to the present discussion and, therefore, is omitted. For purposes of brevity and clearness the data to be discussed below will be analyzed by monthly periods. The procedure to be followed will consist simply of comparing the data from month to month with corresponding environmental features of the water supply and of pointing out such apparent failures in performance as will appear.

DISCUSSION OF DAILY RESULTS

February. The daily quality of the tap water during February is of considerable interest on account of the sharp rise in B. coli content in the period from the 13th to the 20th, inclusive. A gradual subsidence in the content then occurred, with little or no further fluctuation in quality throughout the rest of the month. The cause of the sharp rise in bacterial content is not hard to determine when

we examine the operating records. The sudden deterioration of the tap water in this case, as in others later to be discussed, apparently is not the result of a decreased amount of applied disinfectant, but rather of the failure of the operator to meet the unusual situation created by dangerous meterological conditions.

On February 13, a change was made from the Antietam Creek to the mountain supply, on account of the increasing amount of water in the Edgemont Reservoir. Shortly before this change a condition of thawing set in on the watershed of the Raven Rock and Warner Hollow streams, resulting in an unusually heavy runoff, as shown by the fact that the Edgemont Reservoir gained in water, between February 12 and 18, to the extent of an approximate depth of 27 feet. During this entire period Raven Rock stream was furnishing its quota of accumulated sediment, since this stream was not eliminated until February 20. It comes about, therefore, that the unusual and excessive B. coli content in the tap water from February 13 to 20 was the direct result of the failure of liquid chlorine disinfection to meet adequately the heavy load placed upon it by the character of the raw water. This breakdown in effective chlorination is not at all surprising when it is borne in mind that the waters reaching the chlorine plant during this period of stress were heavily charged with the cumulative sediments of several months of concentrated frozen pollution, ready to be discharged into the supply on the day of an auspicious thawing temperature. The abnormalities of February tap water are so obvious in their causation that further discussion of their origin is unnecessary.

March. March shows a quality of tap water consistently good and superior in daily content to practically any other month under discussion. This condition is particularly striking in view of the fact that March was an unusually warm month and was subject in addition to heavy rainfalls, as of March 9, 13, and 14. Here daily records of a different nature disclose the cause of good results. A study of the record of water elevations in the Edgemont Reservoir, table 1, indicates the interesting fact that during practically the entire month of March the reservoir contained sufficient water to overflow the spillway and *was not drawing water at all from Raven Rock stream.*

Knowing the apparent advantage in the elimination of Raven Rock and the effect obtained in "equalization, sedimentation, and devitalization" with an overflowing reservoir, it is not at all difficult

to understand the decided superiority of the March water over that of February. The March results typify the advantages of dilution of possible entering concentrations of contamination, and the stabilizing effects of large storage capacity. In this month chlorine was effective because it was acting apparently upon a consistently fair water, in which intermittent and sudden increases in contamination and turbidity were avoided by the happy existence of a stabilizing influence, a full Edgemont Reservoir.

April. The good effect of the above condition is further illustrated in the month of April, when from April 9 to 30 inclusive the reservoir at Edgemont was overflowing. The unusual advantage of the combination of circumstances which supplies an overflowing reservoir and permits of the elimination of the Raven Rock water is well brought out by a comparison of the results preceding and those following April 9. The average daily B. coli content (isolation) of the first nine days of April was 1.8 per 100 cc. as compared with a value for the remainder of the month of only 1.0. This is particularly striking in view of the fact that the rainfall in the second period (April 9–30) was far greater than in the first, to wit: 5.7 against 0.04 inches. It is important to note, however, in this connection that in the first period (April 1–9) the Edgemont Reservoir was *not* full and that Raven Rock stream was in use, neither of which conditions existed after April 9. The April environmental and meteorological conditions give excellent evidence as to the desirability of having some natural or artificial medium available to remove the effect of peak loads now placed on most chlorine plants which treat surface streams of markedly fluctuating qualities, without any preliminary auxiliary treatments for levelling uneven and excessive bacterial contents and turbidities.

It is well to point out also that the results for March and April indicate very clearly the advantages which would accrue to the water supply if the Raven Rock intake were reestablished in the Edgemont Reservoir in such a position as to make its effect less predominant.

May. The month of May differs from the preceding two months in two important and correlated aspects: The quality of the tap waters is decidedly inferior to that of March and April and Raven Rock stream was used during the entire month. These two conditions have much in common, provided rainfalls occur at the same time. During the major portion of the month of May the Edge-

mont Reservoir was full, but the use of the Raven Rock stream with a relatively rapid rate of runoff reduced its beneficial effects after each rainfall. A comparison of the rainfall data with the quality of the tap waters indicates that the *Edgemont Reservoir, though full, is not nearly as efficient a stabilizer of raw waters when Raven Rock is used as when it is omitted.* A comparison of the tap water results in March, April and May shows beyond doubt that the use of Raven Rock water, with any rainfall whatever, causes a deterioration in quality of the water, whereas the omission of the same, even with excessive rains, results in a marked improvement. The following comparison will serve to make this situation clearer:

MONTH	MEAN B. COLI PER 100 CC. IN TAP WATER	RAINFALL (CHEWSVILLE) TOTAL INCHES	RAVEN ROCK
March	1.0	2.41	Not used
April	1.8 (April 1–9)	0.04	Used
April	1.0 (April 9–30)	5.7	Not used
May	3.4	2.93	Used

June. The data obtained during the month of June are not characterized by any unusual conditions. The results in general are consistently fair, due possibly to several causes. The tap water quality is generally good because June was a month of extremely low rainfall (a total for the month of 1.89 inches at Chewsville). The absence of atmospheric disturbances of unusual proportions, the beginning of alum dosage at Smithsburg, and the partial use of Antietam Creek water with relatively good conditions, all resulted in making June a "favorable quality" month.

July. July was unfortunate in its results in a number of ways. In the first place, July 1, 2, and 3 appear with abnormally high B. coli contents, due probably to the single important rainfall in the preceding month, namely 0.65 inch on June 30. With the water 15 feet below the spillway in Edgemont and with Raven Rock in use, the effect of this rainfall was not long in making its appearance.

A gradual improvement in the quality of the water followed July 3, with only intermittent and slight amounts of rainfall, whose effects were largely problematical. On June 15 the partial use, and on July 22, the complete use of the Antietam Creek supply was initiated. This period marks an important epoch in the history of the quality of the Hagerstown supply for the first six months covered

by this study. On July 19 only a slight rainfall (0.39 inch) caused a secondary maximum B. coli content on July 20.

The period of July 24 to 31 is a most interesting one, since it indicates certain conclusions relative to changes in those features of the Hagerstown supply which need most attention. The poor results of this period have no other cause than the complete failure of the filtration plant to perform its function. On July 24 and 25 Diffendal stream was turned into Smithsburg Reservoir, but was not allowed to enter the town. The inferior quality of the tap water of July 25, 26, 27, 29, and 30 is completely due, therefore, to the Antietam Creek supply. The cause is not far to seek. On July 24 and 25 a total of approximately 1.6 inches of rain fell in the vicinity of Hagerstown. The raw water of Antietam Creek became a veritable mud, turbidities of 2000 and 1500 parts per million being reported. To meet this unexpected and dangerous condition a dosage of alum of about 0.6 grain per gallon was used, hardly enough even to begin the coagulation, much less to cause any sedimentation. The final disinfection of a water such as the above with a dose of chlorine of 0.6 parts per million had little effect.

August. In the month of August the mistakes of July were repeated with even worse results. The first few days of August were fair. On August 6 and 7 Antietam Creek gave way to the mountain supply. The reason for the change the records at this writing do not disclose. The change was unfortunate. Given, as initial conditions, practically no water in Edgemont, Raven Rock in use, and a rainfall of 0.8 inch the preceding day (August 5), the final outcome was unavoidable, a B. coli content of over 2400 per 100 cc.

On August 8 use of the Antietam Creek supply was resumed and was continued for practically the rest of the month. The bacterial results from August 8 to 31 require but little comment. Here again, history repeated itself. The same cycle of heavy rainfall, excessive turbidity, low and useless alum dosage, followed by disappointingly unsafe tap waters, was traversed twice again during this same month.

September. The quality of the tap waters in September requires little discussion. The correlations shown in this month are largely the same as those pointed out in the previous discussion and the conclusions indicated verify those already reached.

Some reference should be made at this point to the objection frequently raised by the superintendent against the use, at the filter plant, of increased amounts of alum with excessive raw water tur-

bidities. The objection resulted from the belief that such increases in alum dosage would shorten the effective length of operation of the filter units, on account of the supposedly added accumulations of flocculent material on the surface of the beds, with a consequent lessening of plant capacity. Fortunately the objection is contrary to the findings in other plants and to the theory of coagulation. It is true, of course, that the length of run of a filter bed decreases with increases in raw-water turbidities, when the application of alum is properly made. It is *not* true, that with the *same* raw-water turbidity (however excessive), a shorter run will result with a high alum dose than with a low. Exactly the converse happens and is to be expected, since the addition of sufficient alum to a water of high turbidity will cause increased sedimentation in the basins, less flocculent material to pass to the filters, and increased length of filter run. With insufficient alum and high turbidity, decreased settling occurs in the basins, more sediment passes to filters, and the length of filter run is shortened. It is apparent, therefore, that the objections raised to increased dosage of alum are not valid and have resulted actually in inefficient runs.

CONCLUSIONS

The present inquiry into the nature and causes of the variations in the daily quality of the Hagerstown water supply during the first eight months of 1918 has disclosed several interesting phenomena. They are briefly as follows:

Mountain supply. The factors operating to produce excessive bacterial counts in the tap water when the mountain supply is in use are relatively few. In each of these factors the fundamental cause is excessive rainfall. If one could eliminate the excessive rainfalls the Hagerstown supply would be, with the safeguard of disinfection, hygienically safe. Since this condition is unattainable, it is necessary to remove the effects of excessive run-offs. There are apparently several ways of eliminating these effects. These methods have been used unconsciously in the past and their advantages have been demonstrated. The use of a full storage reservoir and the elimination of Raven Rock stream, if entrance of its water is to remain at the present location, or the use of both Warner Hollow and Raven Rock streams with a new point of entrance at the head of Edgemont Reservoir for water from the latter, appear to be most

desirable. In the absence of such initial conditions as noted, the deleterious effects of heavy rainfalls cannot be equalized successfully and hence peak loads are shifted upon the chlorination, with dangerous results.

If the maximum stabilizing and levelling influences of a natural agency, the Edgemont Reservoir, are not at all times available, it is desirable and necessary that the influence of an artificial agency be added. Such an agency exists in the action of coagulation and sedimentation. The findings of this study show beyond reasonable doubt that, in a number of instances, alum *must* be used on the mountain supply, or else the quality of the water suffers immeasurably.

Antietam Creek supply. On the Antietam Creek supply the only sentry between the effects of heavy rainfall and chlorination is the Bridgeport filtration plant. In the mountain supply, it sometimes happens that reservoir conditions are such as to mitigate the results of excessive rainfalls, but on the Creek supply we have unfortunately no such intermittent assistance. The operation of the Bridgeport plant is characterized by a fatalistic recurrence of objectionable tap water with every unusual intensity of rainfall.

The obvious remedy lies in improved operation of the filtration plant. An immediate change must be made, of course, in the present application of alum, with a later modification undoubtedly in the basins used for coagulation and sedimentation.

In the preceding study no attempt has been made to draw fine distinctions between the daily results or to differentiate so-called good from bad waters. The study has been concentrated upon the relative, rather than the absolute, significance of the B. coli count. Interest has been centered upon the endeavor to determine the causes of the wide variations in a single index, the B. coli, and their future removal. Whether the fecal or the soil type of B. coli has persisted in the tap water is of relatively little significance at this time, when we have learned that the factors which produce marked fluctuations in quality in the Hagerstown supply are of such character as to demand their immediate eradication. The purpose of the study has been to determine the deviations from the normal, and not the significance of the absolute, B. coli contents.

CAN PRESENT CLASSES OF PIPE BE REDUCED BY A MATERIAL INCREASE IN THE STRENGTH OF THE METAL?[1]

W. W. BRUSH:[2] The question under discussion is whether an increase of, say, 50 per cent in the strength of the metal of which cast iron pipe is made will probably result in a reduction being made in the number of classes of pipe that are now scheduled in the standards adopted by the American Water Works Association. These standards are placed in two groups, the first group representing pipe suitable for a head of from 100 to 400 feet, and second group, known as high-pressure pipe, covering heads from 500 up to 800 feet. The first group is that which is used for almost all the pipe placed in distribution systems.

The more important question will, then, be whether there can reasonably be omitted any of the present four classes that appear in this group. The answer that ultimately will be given to this question will be based upon the economic advantages or disadvantages that will result to the purchaser from the elimination of any of the present classes. An increase of 50 per cent in the strength of the pipe would make a reduction in the present difference in weight between the various classes, but this reduction would not be directly proportionate to the increase in weight, as cast iron pipe has generally an allowance of $\frac{1}{4}$ inch in thickness to provide for the weakening effect of corrosion, and such allowance would logically not be affected by any modification in the strength of the metal. If the metal were to show a higher resistance to corrosion, as a result of the change which increased the strength of the metal, then this $\frac{1}{4}$ inch allowance might be reduced, but from our knowledge of the relative rapidity of corrosion of cast iron and steel, it seems most unlikely that iron of a higher tensile strength will offer an increased resistance to corrosion.

[1] Informal discussion at a meeting of the New York Section, October 22, 1919. Further discussions are requested, and should be sent to the Editor.

[2] Deputy Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

A tabulation has been made of the percentage that the weights of classes A, B, and D bear to class C, for the various sizes of pipe from 4 inches up to 60 inches in diameter. Class C is used as the unit of comparison, as this pipe, which is designed for a 300-foot head, is the class which would be suitable for the vast majority of distribution systems, assuming that the lighter classes were to be discontinued. It is interesting to note that this comparison shows class A pipe 4 inches in diameter to be 14 per cent less in weight than the similar size class C pipe. This difference in weight increases as the size of the pipe increases, until a difference of 32 per cent is noted for 60-inch pipe.

It is very doubtful whether those who find class A pipe adequate for their needs will be willing to pay the above additional percentage for class C pipe, and it is also doubtful whether the manufacturer would make a sufficiently attractive price on class C pipe to offset any substantial part of this difference in percentage.

Class B pipe shows 7 per cent lower weight for 4-inch pipe, which increases to 18 per cent lower weight for 60-inch pipe. Here again the percentages are substantial, and are virtually the same numerically as those shown for class D pipe. In the high pressure pipe, the variations are very similar to those set forth in the low pressure pipe.

It is the speaker's conclusion that the present classes of pipe, which are designed for variations in head of 100 feet for each class, represent as small a number of classes as the water supply fraternity would be willing to subscribe to, and that no change is to be expected unless the manufacturers can clearly show that a change can be made with a resultant reduction in price of the different pipe to the consumer.

R. W. Conard:[3] The present specifications for cast iron pipe are based on iron that is presumed to have a tensile strength of 20,000 pounds, but as a matter of fact most of the iron that is going into pipes today is of slightly greater strength, running up to possibly 24,000 pounds. When higher standards are given with present foundry mixtures and methods, the elasticity of the iron in pipe is reduced and it becomes harder and more brittle. Probably the question under discussion arose because some manufacturers have been making experiments on high tensile metal. These investiga-

[3]Inspecting Engineer, Burlington, N. J.

tions are understood to involve some method whereby they can produce a pipe which has an elasticity as great as the present iron pipe. There has been, within recent years, pipe produced that has had a higher strength than the present standard, for which probably an extra charge was made.

Iron of greater strength and elasticity than is now used can be put in pipes for about 10 or possibly 5 per cent increase in price. It might be worth giving this consideration, when looked at from that standpoint. There is being consideration given to the question of some possible revision in the specifications for standard cast iron pipe, and the information that might be gathered from a thorough discussion of this question would undoubtedly be of value to the committees that are working on the revision of these specifications.

H. F. Dunham:[4] Unless Mr. Brush has taken into consideration the factors of safety that now obtain in cast iron pipes under specifications that originated largely in the manufacturer's department of this Association, and were named largely by the Association itself, this item or these factors should receive attention.

This suggestion is not entirely new. Years ago, the speaker prepared a table for the different sizes and classes of pipe. Care was taken to avoid confusion resulting from the necessity of making small sizes of a thickness suitable for desirable house connections. If a thickness of wall of 0.42 inch is suitable for 4-inch pipe connections there could be no trouble from a connection with a 12-inch pipe with walls of the same thickness. Therefore the investigation was limited to the larger sizes; twelve inches and above.

Now it would be naturally supposed that with increase in size and in pressure the factor of safety should be also increased. Certainly there would be greater losses in event of failure. But the truth is that in the so-called American Water Works Standard Specification the lesser sizes under the lower pressure have by far the greater factor of safety. For the 12-inch pipe the factors under the different classes range from about 30 for the low heads to about 12 for the high heads and for some of the still larger sizes and high heads the factor is as low as 9. This is all on a basis of 18,000 pounds for tensile strength of cast iron and corrected for a proper reduction in the thickness of the wall of the pipe on account of the variations due to irregularities in core or castings.

[4] Consulting Civil Engineer, 32 West 40th Street, New York, N. Y.

Manufacturers and their salesmen often claim advantags for thick-wall pipe on account of the diminished chance for fractures in the trench after the pipe has been laid. But every superintendent knows that the heaviest pipe can be so laid as to break down under the laws of gravitation and that lighter pipe can be so laid as to be permanent under the same laws. Moreover, for extreme conditions, as where the adjacent earth is liable to be disturbed, special provision can be made. It is not necessary that half a mile of difficult ground should determine the weight of a 40-mile pipe system.

The point to be considered is this: if you are to introduce a superior grade of metal, like semi-steel, with new factors of safety, present factors will be changed and should bear a proper instead of an improper relation to each other. They should be changed in any event.

W. W. Brush:[2] The question raised by Mr. Dunham of factors of safety in the present standards is one in which we are all interested, but is one about which there is a difference of opinion among water works men. Mr. Dunham directs attention to the reduction in the factor of safety as the diameter of the pipe increases. It is generally considered that the greater relative thickness of pipe wall for the smaller size pipe is desirable and probably necessary to avoid danger of fracturing pipe while it is being handled prior to the laying of the pipe. Also that the water hammer is likely to reduce as the size of the pipe increases.

Theoretically there should not be some of the differences in thickness which now appear for the pipes of the different diameters, and the variations in thickness between classes is comparatively small when one considers the large factor of safety. The speaker has been interested in noting that the reasonableness of the difference in thickness for the different classes has been apparently sustained by the experience in New York City, where a larger percentage of breaks on 20-inch pipe than on other size has been noted after the introduction of higher pressures, and the previous New York City standard for 20-inch pipe is relatively the lightest of the various diameters in use.

There appears to be general satisfaction secured when pipe is used of the standard thickness recommended for various heads by the American Water Works Association, and unless it is conclusively shown that these standards are illogical, it would, in the speaker's opinion, be inadvisable to attempt to change them.

THE OPERATION OF AN AMERICAN OR RAPID WATER FILTRATION PLANT FOR TWENTY YEARS AT YORK, PA.[1]

By James M. Caird[2]

There are few water systems which combine storage and stream flow regulation, reforesting, pumping, sterilization, aeration, sedimentation, coagulation and filtration. These agencies are employed by the York Water Company, which supplies water to York, Pa., a city located in the south central part of the state, having a population of about 55,000.

The water supply is obtained from the south branch of the Codorous Creek, the pumping station being located about four miles from the center of the city. The creek, with a drainage area of about 100 square miles above the pumping station, is subject to severe floods, and at times is somewhat polluted. The water always contains some color and turbidity.

In 1912 the storage or stream-flow regulating reservoir was placed in service, having a capacity of 1,000,000,000 gallons and a water surface area of 170 acres. In order to protect this reservoir 570 acres of land were purchased and 300,000 trees planted on the watershed.

The pumping station is equipped with three high-duty steam pumps, one of 8,000,000 and two of 5,000,000 gallons capacity, by which the water is lifted 308 feet for delivery and forced through a 24-inch main to an aerator about 2½ miles from the pumping station.

In October, 1910, a hypochlorite plant was installed at the pumping station, and since that time all water has been treated with the sterilizing reagent before aeration, with the results shown in table 1. These results show that the sterilization reduces the bacteria in the creek water 97.52 per cent before the water enters the sedimentation basins. During this same period 84.92 per cent of the 1 cc. samples of creek water and 14.39 per cent of the samples of sterilized water

[1] Discussion of this paper is requested, and should be sent to the Editor.

[2] Chemist and Bacteriologist, Troy, N. Y.

TABLE 1

Bacterial counts per cubic centimeter (gelatin) of creek water and of water after different stages of treatment, percentage of positive presumptive tests for B. coli, and typhoid fever death rate per 100,000 population

YEAR	CREEK			AERATED			SETTLED			FILTERED			TAP, AVERAGE	PERCENTAGE PRESUMPTIVE TESTS FOR B. COLI 1 CC.					TYPHOID DEATH RATE	TYPHOID CASES
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average		Creek	Aerated	Settled	Filtered	Tap		
1899			5,543	19,900	2,400	5,543	132,000	1,000	1,166	700	5	38		100	100	100	2	0	84.6	131
1901							480	120	257	60	6	18		100	100	100	2	0	41.5	105
1902			1,975	2,700	1,150	1,975	1,080	190	545	10	2	4		100	100	80	2	0	29.7	87
1903			2,090	5,380	680	2,090	1,170	62	413	15	1	3	6	100	100	45	0	0	11.8	39
1904			2,167	3,950	290	2,167	785	102	276	4	1	2	2	100	100	40	2	0	32.6	29
1905			1,463	2,190	880	1,463	890	200	442	6	1	1	1	100	100	49	0	0	17.8	71
1906			969	1,600	686	969	334	175	233	4	1	2	2	87	87	33	17	0	15.3	79
1907			7,485	21,500	2,080	7,485	3,233	750	1,410	29	1	9	13	85	85	45	0	0	30.7	96
1908			620	760	510	620	690	220	413	110	3	20	29	90	90	90	2	0	15.3	45
1909			6,618	111,300	260	6,618	22,950	33	1,272	1,300	1	41	26	92	92	69	2	0	15.3	66
1910			10,715	62,000	57	8,380	30,100	1	2,553	1,000	1	84	42	93	72	43	0	0	11.2	74
1911	120,000	3,245	42,367	1,900	1	129	126,500	1	2,889	1,600	1	15	23	92	12	11	0	0	24.6	102*
1912	6,450	850	3,650	12,250	19	473	29,880	8	1,572	2,240	1	70	54	87	11	6	0	0	8.9	54
1913	53,600	980	14,191	2,310	20	190	171,000	30	1,420	1,420	1	49	4	73	24	19	0	0	8.9	86
1914	59,500	485	7,624	19,050	30	469	29,200	30	1,500	880	1	23	13	76	17	12	1	0	8.9	94
1915	44,300	580	6,694	4,400	25	260	129,000	6	6,520	2,290	1	83	32	85	13	9	0	0	19.2	170†
1916	72,000	600	7,812	11,300	20	271	235,200	20	6,729	170	1	8	16	90	14	12	0	0	15.3	64
1917	38,700	515	10,505	4,650	26	212	35,750	20	1,667	1,458	1	30	17	100	16	9	0	0	13.4	46
1918	51,000	570	9,351	32,500	20	485	3,650	10	208	209	1	4	2	77	9	9	0	0	11.4	64‡
Ave..	55,694	978	7,880	17,758	509	2,211	50,205	157	1,657	711	2	27	18	91	60	41	2	0	22.6	79

* Includes 34 cases due to milk.

† Includes 60 cases due to ice cream.

‡ Includes 13 cases due to milk.

Note: The figures for aeration also cover the sterilization of the water at the pumping station since October, 1910.

contained B. coli. This treatment therefore reduces this organism 83.07 per cent. The average amount of hypochlorite used was 6.52 pounds per million gallons of water.

There has also been installed at the pumping station sulphate of alumina tanks, so that any time it should become necessary to pump water containing a turbidity of over 500 parts per million, some coagulant could be added, thereby materially assisting sedimentation in the large basins, and relieving the load from the filters. The capacity of the sedimentation basins is such that up to the present time it has not been necessary to operate the pumps during periods of high turbidity.

After aeration the water flows to two brick-lined sedimentation basins which, having a combined capacity of about 40,000,000 gallons, afford from 10 to 14 days sedimentation of the water before it passes to the filters. This water, even after treatment with the sterilizing agent and thoroughly saturated with oxygen by aeration, supports algae growths. The water develops a strong "mouldy" odor and taste, the principal organisms present being oscillaria and anabaena. At these times considerable trouble is experienced in operating the filters, due to the rapid clogging of the sand beds. This causes the filters to require frequent washings, and as filtered water is used in washing and has to be pumped, the operating expenses are thereby increased.

At these times the water in the basins is treated with copper sulphate and after a few hours normal conditions are restored. The bacterial content of the water increases greatly after the copper sulphate treatments.

Table 1 shows that the bacteria were reduced 25.1 per cent by sedimentation.

During the twelve years before the sterilizing reagent was used, the basins reduced the bacteria 75.9 per cent; while during the eight years that the water has been sterilized before entering the basins the bacteria increased from an average of 314 to 3748 per cc., or 1093 per cent. This increase is due to a secondary growth and also the growth which follows the copper sulphate treatments, and is not unusual in a treated stored water.

During the 19 years the basins reduced the B. coli at least 31.4 per cent. During the 11 years before the sterilizing reagent was used, the basins reduced the B. coli 32.5 per cent while during the 8 years that the sterilizing reagent has been used this organism has been reduced 23.4 per cent.

Table 2 shows that the basins reduce the turbidity 62.4 per cent and produce a very uniform water for filtration.

The storage of this water in the sedimentation basins exposed to air and light reduces the color 41.9 per cent.

The sedimentation basins are drained and cleaned about every second year.

TABLE 2

Color and turbidity of creek water and water after various stages of treatment, sulphate of alumina used in grains per gallon, and percentage of water used for wash

YEAR	TURBIDITY								ALUM	WASH WATER	COLOR							
	Creek Average	Aerated			Settled			Filtered Average			Creek Average	Aerated			Settled			Filtered Average
		Maximum	Minimum	Average	Maximum	Minimum	Average					Maximum	Minimum	Average	Maximum	Minimum	Average	
1899					12	8	10	0	1.62	3.00					20	7	17	0
1901					100	7	39	0		3.90								
1902		500	12	39	50	35	41	0	0.50	2.57					40	12	25	0
1903	45	65	16	45	15	7	9	0	0.89	2.26		55	30	42	35	25	32	0
1904	43	60	35	43	16	8	11	0	1.01	1.84		45	20	33	28	15	20	0
1905	82	140	50	82	28	7	13	0	1.00	2.60		45	25	35	18	13	16	0
1906	31	50	26	31	13	8	10	0	1.02	3.60		22	18	19	50	15	27	0
1907	141	800	30	141	13	8	11	0	1.19	2.27		70	15	31	30	12	18	0
1908	23	35	16	23	16	6	10	0	1.24	2.56		28	15	20	22	15	18	0
1909	28	40	22	28	10	7	9	0	1.25	3.60								
1910									1.41	2.78								
1911	116	3,000	8	126	180	7	31	0	0.66	2.05					20	6	12	0
1912	78	5,000	10	147	500	15	46	0	0.73	2.14					11	7	10	0
1913	71	4,000	10	85	160	10	41	0	0.65	2.13		40	18	31	12	8	10	0
1914	67	1,000	20	75	200	12	39	0	0.68	2.27		35	12	25	15	9	11	0
1915	115	640	10	92	240	13	49	0	0.68	2.24		30	20	26	20	3	11	0
1916	61	400	15	51	140	10	28	0	0.64	2.04	29	35	20	26	15	8	10	0
1917	122	360	10	97	280	10	56	0	0.61	2.02	23	30	12	21	13	7	9	0
1918	74	560	10	68	240	10	44	0	0.55	1.99	17	18	12	16	20	5	9	0
Average..	73	1,041	19	73	123	11	28	0	0.91	2.54	23	38	18	27	23	10	16	0

The water flows from the sedimentation basin to the filters, and the sulphate of alumina which is used as a coagulant is pumped into this water. The coagulant feeding device is novel and works with entire satisfaction. It consists of a set of fans or propellers located in the main leading to the filters and connected to a shaft and gearing which, in turn, operates the pump. The amount applied can be regulated by the stroke of the pump and the size of the plunger. The average amount applied during the past 19 years was 0.91 grain per gallon or about 132 pounds per million gallons of water

treated. At no time has any of the sulphate of alumina which is used as a coagulant been found in the filtered water, although large samples of the water are frequently tested.

The average alkalinity of the unfiltered water was 21.3, while that of the filtered water was 15.1 parts per million, showing that 6.2 parts per million are used by one grain of sulphate of alumina per gallon of water treated. It has not been necessary to use lime or soda-ash at any time, as the alkalinity has always been sufficient to decompose more sulphate of alumina than is required to properly coagulate the water.

Shortly after this plant was placed in operation an attempt was made to use sulphate of iron and lime as the coagulant, but the results were not satisfactory.

The filter building originally contained 8 high-type Jewell gravity filters, but in 1908 four additional filters were installed, so that at the present time the plant contains 12 units, each having a normal capacity of 520,000 gallons per day.

Each filter is 16 feet inside diameter, the total sand area being 2117 square feet or about one-twentieth of an acre.

The filter bed consists of 5 inches of graded gravel and 25 inches of sand. The mechanical analysis of the sand shows the effective size to be 0.62 mm., and the uniformity coefficient 1.12.

The filter tanks, which are of $2\frac{3}{4}$ inch cypress, show some decay in a few places; from time to time it has become necessary to replace some of the bands.

The strainers in the filters are known as "C-J," manufactured by the New York Continental Jewell Filtration Company. It has been found necessary to repair some of these strainers about every 6 years. They are repaired by removing the old rivets and gauze, and replacing the gauze and rivets, the men at the plant doing this work. There are 702 strainers in each filter, spaced on 6-inch centers.

The filters are equipped with loss of head gauges and Weston automatic effluent controllers.

The water to be filtered is first treated with a solution of sulphate of alumina. The sulphate of alumina is dissolved in two solution tanks, each having a capacity of 1500 gallons. This solution is prepared by weight and it has been found that a strong solution will react more quickly and better than a weak one.

The amount of solution applied depends upon the condition of the water and the temperature. In warm weather the action is quicker and less solution is required than when the temperature of the water is low. The average amount of sulphate of alumina used during the 12 years before the sterilizing reagent was used was 1.11 grains per gallon, while during the 8 years in which the sterilizing reagent has been used the average was 0.65 grain per gallon, showing a saving of 41.5 per cent. The minimum amount of sulphate of alumina which will form any coagulation is about 0.25 grain per gallons; if less is used no coagulation is visible.

After treatment with sulphate of alumina the water passes to the coagulation basin under each filter, and is there retained from 20 to 30 minutes. In passing through the coagulation basin about 30 per cent of the suspended matter is removed.

The water then passes to the top of the sand. After passing through the sand it is discharged into the filtered water reservoir directly under the filters. This reservoir has a capacity of 225,000 gallons and is connected with another covered reservoir of about 2,000,000 gallons capacity. From these reservoirs the water flows to the consumers. The reservoirs are of such capacity that it is possible to operate the filters at a uniform rate at all times.

When the filters become "clogged," it is necessary to wash them by pumping filtered water up through the beds, the amount used being about 10 gallons per square foot of sand surface per minute. During the washing the mechanical rakes are operated. The average amount of wash water used during the past 20 years was 2.54 per cent of the water filtered. A filter is out of operation about 7 minutes per wash.

During the first few years after the plant was in operation it was customary to "sterilize" the sand beds every six months. This was done by placing about 300 pounds of soda-ash on the surface of the sand bed and then introducing steam through the strainer system until the beds boiled for one hour. While this treatment cleaned the sand grains, it was found that it would be at least a week before the bacterial efficiency would be satisfactory, therefore the "sterilization" has not been used during the past 17 years.

When this plant was first placed in operation bacterial examination of water was in its infancy. There were no chemical or bacterial tests made during 1900. Previous to 1904, chemical and bacterial tests covering periods of a week were made several times

each year. Since that time an extensive laboratory has been maintained and daily chemical and bacterial tests are made. Since the daily chemical and bacterial tests have been made it has been possible to keep the plant under control at all times and the results obtained show a better efficiency and more uniform results.

In determining the bacterial content of the water it has been found that gelatin media at 20°C. for 48 hours is the most satisfactory. In determining the bacterial count all plates are made in duplicate and the average count reported. A large percentage of the filtered water and city tap plates are incubated for 72 hours and remain sterile at the end of this period. All sterile plates are recorded as containing one bacterium per cubic centimeter.

Several times the filter beds have become "seeded" and at such times the agar bacterial plates did not indicate the true conditions.

During the entire 20 years the filtered water has always been free from color and turbidity.

The extreme maximum bacterial content of the unfiltered water always follows the copper sulphate treatments of the water in the sedimentation basins.

The extreme maximum bacterial content of the filtered water comes when the beds are "seeded" and does not mean that this number of bacteria are passing the filters from the unfiltered water.

All these maximum bacterial counts are included in the averages. The results show that the filters remove 98.37 per cent of the bacteria.

The average results in table 1, modified to show the effect of sterilization in 1911-1918, show that the bacteria were reduced 97.52 per cent by sterilization; 25.06 per cent by sedimentation; 98.37 per cent by filtration and 33.34 per cent in passing through the filtered water reservoirs and the city mains.

The total reduction for the system from creek to city tap was 99.77 per cent.

The agar counts on creek water were 74.64 per cent less than gelatin; aerated 50.14 per cent; settled 37.98 per cent; filtered 72.47 per cent and city tap 85.14 per cent. These results show that agar media incubated for 24 hours at 37½°C. prevent the growth of a large number of organisms when compared with the gelatin counts incubated for 48 hours at 20°C.

Aeration did not remove any of the B. coli, but sterilization removed 83.07 per cent; sedimentation 31.44 per cent; filtration

95.80 per cent and the passage through the filtered water reservoir and mains 100.0 per cent.

Although thousands of samples of the city tap water have been examined for B. coli, its presence has never been discovered.

The average turbidity of the creek water is higher than at the fountain, as the aerator is not operated at times of high turbidity.

The sedimentation basins remove 65.16 per cent of the turbidity, while the filters remove 100.0 per cent of the turbidity that passes the basins.

Aeration and sterilization do not remove any of the color. Sedimentation and storage, exposed to air and light, removed 43.21 per cent; while the filters removed 100.0 per cent of the color that passed the basins.

TABLE 3

Average bacteria per cubic centimeter, special tests, creek, aerated and sterilized, settled, filtered and city tap water, gelatin incubated 48 hours at 20°C.; agar incubated 24 hours at 37½°C.

YEAR	CREEK		AERATED		SETTLED		FILTERED		TAP	
	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar
1911	2,440	1,610	543	364	1,702	1,666	14.0	5.0	18.0	11.0
1912	15,033	3,533	1,578	580	1,180	274	148.0	14.0	133.0	7.0
1913	1,250	533	133	73	106	73	28.0	26.0	14.0	9.0
1914	641	248	88	45	55	25	7.0	0.8	10.0	0.1
1915	2,117	1,137	254	159	166	111	5.0	4.0	10.0	10.0
1916	758	500	137	79	868	538	15.0	10.0	8.0	6.0
1917	6,458	2,165	162	112	203	51	2.0	0.5	1.0	0.7
1918	10,066	108	73	64	145	83	2.0	0.4	2.0	0.5
Average	4,845	1,229	371	185	553	343	27.6	7.6	37.0	5.5

Table 2 shows that a very small amount of sulphate of alumina is required to remove the color and turbidity, while the amount of water used in washing the filters is very reasonable.

During the seven years (1892-1898) before the filter plant was in operation, there were 769 cases of typhoid fever, with 104 deaths, the death rate being 58.1 per 100,000 population.

During the twenty years (1899-1918) that the filter plant has been in operation there have been 1582 cases of typhoid fever, with 170 deaths, the average death rate being 22.6 per 100,000 population, making a reduction of 61.1 per cent in the death rate.

The average typhoid fever death rate during the 12 years that only sulphate of alumina was used was 28.5 per 100,000 population; compared with the rate before filtration this is a reduction of 50.9 per cent in the rate.

During the 8 years in which the sterilizing reagent has been used with the sulphate of alumina, the typhoid fever death rate has been 13.8 per 100,000 population. Compared with the rate when sulphate of alumina was used, this is a reduction of 51.6 per cent, and if compared with the rate before filtration was introduced the reduction would be 76.3 per cent in the typhoid fever death rate.

The entire improvement in the typhoid fever death rate is not due to the improvement in the public water supply. It is not the intention to imply that all typhoid fever is due to impure water. There are many other means of conveying this disease. The proper purification of water will only prevent typhoid fever previously due to impure water.

The data in table 1 do not show that there is any connection between the bacteria and B. coli in the filtered water and the typhoid fever death rate.

A study of the results will show that the operation of the York water purification plant has been very successful. Charles W. Graff has been superintendent of the filter plant and resident chemist and bacteriologist since 1902. The officers of the York Water Company are: Charles Kurtz, president; Samuel Small, Jr., vice-president; Smyser Williams, secretary; J. J. Frick, treasurer, and Edgar P. Kable, general manager.

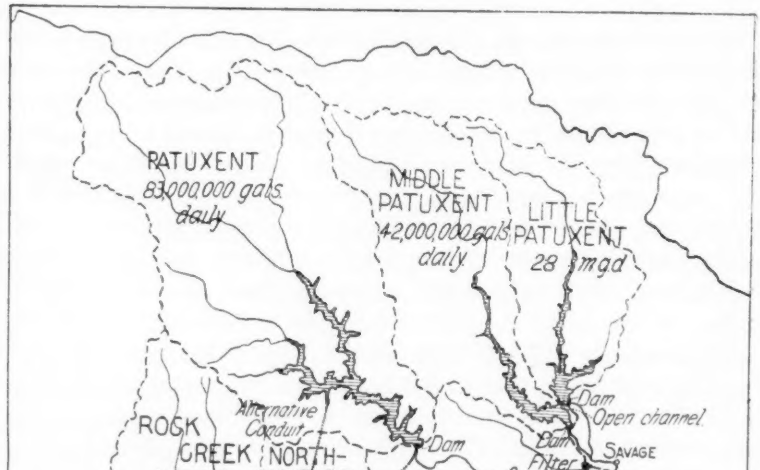
MORE WATER FOR GREATER WASHINGTON[1]

The population of the District of Columbia began to spread over the District boundaries a good many years ago. About four years ago the suburban development in Maryland adjoining the District had so grown that the Washington Suburban Sanitary Commission was created by the Maryland legislature to provide water supply and sewerage facilities for a considerable population which is a part of that of the District of Columbia except for government and public works purposes. When the Commission was organized it was believed that water could be bought from the District of Columbia for the larger part of this suburban population, but the very rapid increase in the population of the District has not only made this impracticable at present but has begun even to tax the capacity of the District works for the needs of Washington itself. It was soon evident, therefore, that while the Commission should relieve the conditions existing in certain suburban communities by building at once a temporary filtration plant of 1,500,000 gallons capacity near Hyattsville, it was desirable to ascertain if it were practicable to build works capable of supplying both the District and the suburban territory about it for a long period to come at a reasonable expense.

It has long been recognized that any further development of the present District supply from the Potomac River will be costly. Some years ago Allen Hazen pointed out that it might be advisable to obtain an additional supply from the watershed of the Patuxent River, northeast of the city, and an investigation of the proposition was made under the direction of Colonel Langfitt. The author's investigations have indicated that the additional water supply needed for the thickly settled and rapidly growing parts of Maryland adjoining the northern and northwestern boundaries of the District of Columbia can probably be obtained from the Patuxent or nearby watersheds, which lie wholly in the State of Maryland, more advan-

[1]Review by the Editor of a report by Robert B. Morse, Chief Engineer of the Washington Suburban Sanitary District, and Chief Engineer of the Maryland State Board of Health.

tageously than elsewhere. As it is manifestly desirable to have the watersheds developed so as to furnish water as needed to the whole Washington metropolitan district, the author has made a study of possible methods of providing such a joint interstate supply.



Map of Watersheds Which Can be Utilized in Obtaining a Supply for Greater Washington

The Patuxent, Middle Patuxent and Little Patuxent watersheds under consideration are shown on the accompanying map. They are sparsely populated and any large increase in their population is improbable. Sources of pollution of the water can be controlled easily, and the water is superior, in softness, appearance and in sanitary quality, to that of the Potomac whence the District supply is drawn. The quality of the water will be further improved by storage in impounding reservoirs of the size needed to furnish a metropolitan supply. The development of these sources offers to the District of Columbia the advantage of an entirely new and independent system of works, so that any accident to the old Washington aqueduct will not leave the national capital without water, a possibility that caused anxiety during the World War. It has also been ascertained that a gravity supply can be furnished in this way to a part of the District of Columbia to which water must now be pumped.

In view of the conditions in both the District of Columbia and the Washington Suburban Sanitary District it is desirable to develop an additional supply as soon as possible, and time needed for construction is, therefore, an important feature of any project. There are two of these projects for an additional water supply which are much better in this respect than the others that have been suggested. The first of these contemplates the immediate development of a supply of 83,000,000 gallons daily from the Patuxent River and 17,000,000 gallons from Northwest Branch. As more water is needed the Middle Patuxent River can be developed to furnish 42,000,000 gallons daily and 28,000,000 gallons can be obtained from the Little Patuxent.

The Patuxent River reservoir can be developed to store 23,500-000,000 gallons by constructing an 80-foot dam. With the spillway at El. 350 and by drawing water down to El. 318, there will be a useful storage of 18,500,000,000 gallons. The water would flow through a conduit about 25,000 feet long, mostly in tunnel, to a reservoir on Northwest Branch. This conduit would have a capacity of about 108,000,000 gallons per day with extreme low water in the Patuxent River reservoir. The Northwest Branch reservoir formed by a dam about 70 feet high, would have a capacity of 6,500,000,000 gallons, of which about 3,500,000,000 gallons would be available for distribution. The spillway is at El. 310 and the reservoir can be drawn down to El. 295. The water would be taken

from it through a conduit of a capacity of 140,000,000 gallons daily to a 100,000,000-gallon filtration plant near the present Brightwood reservoir of the District of Columbia water works.

The later developments under this first project would be the construction of a 15,500,000,000-gallon reservoir on the Middle Patuxent River by means of a 105-foot dam. About 11,500,000,000 gallons of the total stored water would be available for use. The Little Patuxent River reservoir would be formed by a 55-foot dam and hold about 6,000,000,000 gallons, of which 5,800,000,000 gallons could be utilized. This last reservoir will have no spillway and will be connected with the Middle Patuxent reservoir by a short open channel. In extreme dry weather the Middle Patuxent reservoir can be drawn down to El. 277 and the Little Patuxent reservoir to El. 280.

The water from these reservoirs would be taken through a conduit of 100,000,000 gallons daily capacity, 8500 feet long, to a 70,000,000 gallon filtration plant near Savage. A 100,000,000-gallon conduit, about 102,000 feet long, would deliver the filtered water to the District of Columbia distribution system, and by constructing a pumping station near Savage water can be supplied to the district about that place and to Camp Meade.

The second project which is attractive from the viewpoint of the time saved in its execution comprises the immediate development of 83,000,000 gallons per day from the Patuxent River and a conduit to Northwest Branch, as in the first project. Northwest Branch would be developed to yield 17,000,000 gallons daily by building a 70-foot dam, at a point about one mile downstream from that under the first project, and forming a reservoir of 4,000,000,000 gallons capacity, of which 3,300,000,000 gallons would be available above El. 260, the minimum useful level in this basin. The spillway would be about El. 290. The water of Northwest Branch would be supplemented by that delivered through an 11,500-foot conduit, furnishing about 36,000,000 gallons daily from Rock Creek reservoir. This last reservoir would be formed by a 73-foot dam and would hold about 13,500,000,000 gallons, of which 7,500,000,000 gallons would be available above El. 275, the lowest useful level. The spillway would be at El. 293. The water would be taken from Northwest Branch reservoir through a 14,500-foot conduit with a daily capacity of about 175,000,000 gallons to a 130,000,000-gallon filtration plant near Takoma Park. The water would be delivered

to the District of Columbia distribution system near the present main pumping station. The later development under this project would be the same as under the first project.

While either one of these projects cannot furnish water from the Patuxent basins in less than five or six years, it should be possible to supply 17,000,000 gallons daily from Northwest Branch in not over three years. If work on the Patuxent River dam and the tunnel between the Patuxent River and Northwest Branch reservoir were carried on simultaneously with the development of Northwest Branch, or if similar work for developing Rock Creek were so carried on, much time in completing either project would be saved. As soon as the first part of one of these projects is finished so that the entire Washington metropolitan district can be supplied by it, the suspension of the present Potomac River works is recommended, keeping them in condition for use as a reserve in case of emergency. As there is a fall of about 140 feet between the present aqueduct near Georgetown reservoir and the Potomac River, the aqueduct might be utilized to furnish water for a hydro-electric plant in the District of Columbia.

The second project will furnish more water than the first, but the latter gives higher pressures and the filtration plant would be located on property of the District of Columbia. If the first project is adopted the Washington Suburban Sanitary District must build its own filtration plant near Takoma Park. Either project is capable of several modifications. No attempt has been made to prepare estimates of the cost of these works, for the purpose of the investigation has been solely to discover feasible methods of supplying the entire Washington metropolitan area with more water from a single system of works at the earliest possible date.

THE NECESSITY OF COMPETENT SUPERVISION AND CAREFUL LABORATORY CONTROL IN THE OPERATION OF WATER PURIFICATION PLANTS[1]

By Lewis J Birdsall [2]

Eternal vigilance is the price of pure water. Every water purification plant from the smallest liquid chlorine installation to the largest and most complete filtration plant should be operated under competent supervision and careful laboratory control.

The cheapness and demonstrated effectiveness of liquid chlorine as a sterilizing agent for water supplies have induced many water works officials in Minnesota, as elsewhere in the United States, to rely on chlorine as the sole means of water purification. Such an installation may, however, merely afford a false sense of security. Failure to keep up the chlorine treatment continuously and in amount sufficient for sterilization of the water may mean a typhoid fever epidemic in the community. This danger is greatest among the smaller water works plants where one man is frequently responsible for the operation of the pumps and the chlorine machine. The result is that the pumps get most of his attention and the chlorine machine is neglected.

There are many water works plants, and among them some that are not small plants, that rely for chlorine sterilization on one machine only, so that when it is necessary to change chlorine cylinders or to make necessary repairs, the chlorine feed has to be discontinued. Too much stress cannot be placed on the necessity of duplicate installations of liquid chlorine machines wherever used, so that when one machine is taken out of service the other may be put in service immediately and continuous treatment be obtained. There should also be kept on hand a supply of extra parts for the chlorine machines, so that ordinary repairs may be quickly made in case of emergency.

[1] Read before the Minnesota Section, December 6, 1919. Discussion of this paper is requested and should be sent to the Editor.

[2] Superintendent of Filtration, Water Works Department, Minneapolis, Minn.

Our state boards of health should require duplicate installations of liquid chlorine machines and it would also appear that the manufacturers of the machines might be led to see the advantage to themselves as well as to the various communities served, in making a substantial reduction in the selling price of two machines to the same purchaser as compared with the price of one machine. The price of repair parts should also be kept as low as possible and all users of the machines be urged to keep a supply of extra parts on hand.

Chlorine cylinders that are in service should be placed on scales and a record be kept of the weight of the cylinders every hour, not only as a check on the manometer gauge of the chlorine machine but also to accustom the operators of the plant to inspect the machines frequently to see that they are working properly. The scales prevent chlorine cylinders from going empty unexpectedly and the recorded weights serve as a check on the faithfulness of the operator provided that the amount of water treated each hour is accurately determined.

But how shall we know that we are adding the proper amount of chlorine to the water in order to obtain sterilization at all times? There is no general rule for the amount of chlorine to use. The suspended matter, dissolved organic matter and the bacterial content of surface waters, especially river waters, are constantly changing. The amount of chlorine necessary for sterilization of the water is influenced by all three of these factors. A filtered water or a fairly clear and pure water requires less chlorine than does a turbid water or one containing a large amount of dissolved organic matter. Whereas a treatment of 0.3 part per million ($2\frac{1}{2}$ pounds of chlorine per million gallons) may be satisfactory in the first case, a much larger dose is required in the latter instance. Residual tastes and odors must be considered in the treatment of some unfiltered waters. A slight variation in the amount of chlorine added may mean either under-treatment and lack of sterilization or over-treatment and complaints from the water consumers. Sterilization takes place less readily in cold water than it does in warm water, and so it is necessary to allow a longer period for the reaction in winter than in summer. Experience has shown that free chlorine disappears much more rapidly from the treated water when the water is passed through iron pipes than when it goes through a concrete conduit.

It is evident that in order to regulate the chlorine treatment properly there must be laboratory control. The test for free chlorine in the treated water, and the determinations of the number of bacteria and the presence or absence of B. coli in the untreated and treated waters offer such control tests. Because of the lag of 48 hours in the results of the bacteriological tests made necessary by the incubation of the inoculated media, it is advisable in most plants to add sufficient chlorine to the water to produce a slight residual free chlorine content of approximately 0.05 part per million. Some waters, as stated above, do not permit of over-treatment, but such waters are comparatively few, and where they occur, the treatment requires very careful supervision. In the majority of cases, therefore, the chemical test for free chlorine becomes the one on which we rely for sudden changes in the chlorine treatment, and the test should be made several times each day. The bacteriological tests indicate the results of the treatment and demonstrate the purity of the treated water. They should be made daily on both the untreated and treated waters.

Chlorine is comparatively cheap, much cheaper than human lives, and therefore it is much more desirable to over-treat a water supply with chlorine than to under-treat it, if reliance for purification is placed on chlorine alone. A chlorine taste in the water, even though it may be unpleasant, is less harmful to the water consumers than a tasteless water that contains typhoid bacilli.

Chlorine sterilization is a valuable adjunct to other methods of water purification, but it should not be depended upon as the only line of defense between a seriously polluted water supply and the water consumers, unless it is so used as a temporary expedient and then only under the most careful supervision.

The laboratory tests necessary for the control of a filter plant are more comprehensive and elaborate than those described for a chlorine plant. Turbidity, color, alkalinity and the bacterial content of the untreated water usually determine the amount of chemical necessary for proper coagulation of the water before it goes to the filters. The same tests on samples of the water as it goes to the filters from the coagulation basins determine the efficiency of the pre-treatment. A properly coagulated and filtered water should have no turbidity and a color of 10 parts per million or less. The bacterial content of the filtered and sterilized water

should be as near zero as possible and B. coli should be absent in 50 cc. amounts of the water.

An odor in the untreated water may be caused by algae and a microscopical examination of the water will disclose the offending organism. Odors from manufacturing wastes are sometimes more difficult to eliminate from the water than are those from micro-organisms. Tests for odor should be made on both the untreated and the filtered water.

The alkalinity test demonstrates the presence of carbonates and bicarbonates in the untreated water, and whether or not they are sufficient in amount to decompose the coagulant to be added. The filtered water should at all times have residual alkailinity as a safeguard against the presence of undecomposed coagulant.

Free carbonic acid frequently occurs in surface waters. A determination of the amount present should be made where lime is used in conjunction with iron sulphate as coagulant. The amount of free carbonic acid in the filtered water should be determined because of the part it plays in the corrosion of exposed iron surfaces in distribution pipes.

The test for residual chlorine is essential, as already described above.

Total hardness tests are made at intervals for the purpose of record. Complaints regarding the hardness of the water supply are more easily answered if data are at hand to show that the filtered water is no harder than the untreated water and that the hardness of the water is greater at certain times of the year due to natural causes.

Complete sanitary chemical and mineral analyses of the untreated and filtered waters are made each month in the larger filtration plants for the purpose of record. These data are not necessarily essential for the proper operation of the plant but they are of value for reference.

Analyses of the chemicals used for water purification are valuable and there should be frequent tests of the chemical solutions that are added to the water.

The most essential laboratory tests for the proper control of a filtration plant are those for turbitity, color, alkalinity, residual chlorine, number of bacteria per cubic centimeter and B. coli. The data obtained from these tests will enable the operator to handle his plant economically and efficiently. He will at all times have the

satisfaction of knowing the quality of the untreated water and the degree of purification obtained by the plant. The health of a community is the final test by which the purity of a water supply is judged, but the operator of a water purification plant who knows each and every day that the water he is supplying is of the highest purity has nothing to fear from health statistics.

A water softening plant requires certain special laboratory tests in addition to total hardness, alkalinity and free carbonic acid determinations. Only under laboratory control can a softening plant be properly operated.

It seems almost inconceivable that anyone should attempt to operate a water purification plant without daily laboratory control tests, but experience has shown that many plants are so operated. An occasional bacteriological analysis of a water supply, whether monthly or weekly, has little significance. It merely shows the condition of the water at the time the sample was taken. The splendid work of the Sanitary Division of the Minnesota State Board of Health is tending to raise the standard of water purification plants in Minnesota and to demonstrate that the saving of human lives rather than dollars is the high ideal we should have constantly before us.

Texas has set an example to other states by organizing a short course for water works superintendents and purification plant operators at the University of Texas. The local sections of the American Water Works Association can do no greater good for their communities than by stimulating interest in the organization of similar courses of instruction in their state universities and then urging the water works men to attend these courses. The farmers long ago realized the value of short courses at the State University and now attend them annually. Why cannot the Universities do for the water works men what they have done for the farmer? The possibilities for education in this new field are unlimited.

Many small water purification plants are unable to pay the salary of a competent analyst. Such plants no doubt have some employee who could learn to perform some of the more simple routine tests, such as those for turbidity, color, alkalinity and free chlorine, provided the necessary chemical solutions are prepared for him. The bacteriological tests are somewhat more difficult, but even these can be performed by such an employee if he shows an aptitude for the work and provided the necessary media can be furnished. A

competent water purification expert could no doubt be employed by a number of such plants at a comparatively small expense to train the operator, interpret the laboratory results thus obtained, furnish the necessary chemical solutions and bacteriological media, supervise the general operation of the plant, and visit the plant periodically. Such an arrangement obtains in some sections of the United States and has been found to work very satisfactorily.

A water purification plant that is operated without laboratory control is merely furnishing a false sense of security to the community. The same plant when operated under laboratory control and competent supervision can and should yield a safe and pure water at all times.

LAYING AND REPAIRING A 12-INCH SUBAQUEOUS MAIN TO NORTH BROTHER ISLAND, NEW YORK[1]

By Patrick Quilty[2]

The City of New York, acting through its Department of Water Supply, Gas and Electricity, awarded a contract for "furnishing, delivering and laying a 12-inch water main across the East River from East 140th Street to North Brother Island, and hauling and laying water mains in East 140th Street and on North Brother Island, Borough of The Bronx," on May 17, 1915. The time allowed under this contract for the completion of the work was 100 working days, and work was commenced on June 7, 1915.

The hauling and laying portion of this contract was practically completed before the end of September, 1915, and consisted of hauling and laying pipes, valves and hydrants furnished by the Department. The flexible jointed pipe furnished by the contractor was laid by him across the East River, including the shore connections, between September 22 and November 16, 1915. The distance across is approximately 1700 feet, figure 1, and the actual length of the pipe line between valves is 1843 feet. The valve on the Bronx side is 83 feet from the edge of the dock in the New York Central Railroad yard through which this pipe is laid. The valve on North Brother Island is about 60 feet from the sea wall. The type of flexible joint used is shown in figure 2; the groove for facilitating the pouring of the lead was first used in the repair work described later.

In prosecuting this work, when about 200 feet from the Bronx shore, the end of the pipe line became disconnected from the lighter and went to the bottom of the river. In recovering and raising the pipe, the hubs of two lengths were broken and it was necessary to remove ten lengths in order to get out these two. In the ten days from October 14 to October 23, inclusive, 113 lengths of pipe were laid. Each length is 12 feet and weighs approximately 2400 pounds.

[1] Read before the New York Section, October 22, 1919. Discussion of this paper is requested and should be sent to the Editor.

[2] Assistant Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

The force consisted of 1 foreman, 4 sailors, 1 calker, 1 leadman, 1 engineman and 1 night watchman. Besides the lighter, a tug and a row boat were in use. The depth of the river at this location is 80 to 90 feet.

The contractor was not successful in obtaining the test called for by the specifications. The following extract is taken from section 83 of the specifications:

. . . . After the flexible jointed pipe is in place it shall be subjected to a water pressure of 70 lbs. per square inch. Under this pressure the leakage from the flexible jointed pipe shall not exceed the rate of fifteen (15) gallons for 24 hours per linear foot of joint distribution over the entire section, the

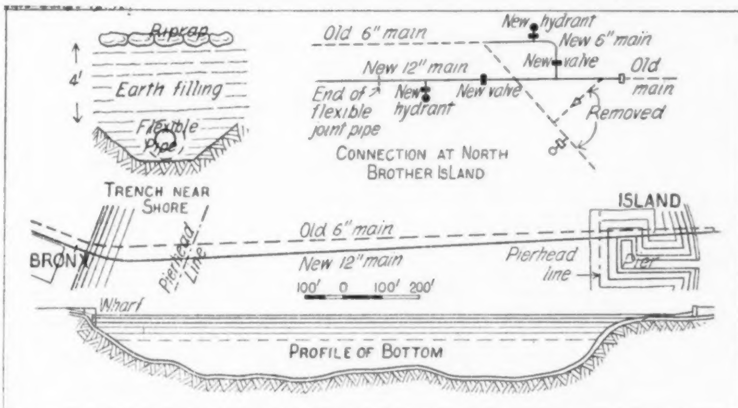


Fig. 1. Subaqueous Main to North Brother Island

length of each joint being figured on the nominal interior diameter of the pipe . . . . After the pipe has been filled with water, the pressure of 70 lbs. per square inch shall be applied and maintained for 30 minutes, during which time the amount of water forced into the pipe shall be determined. This measurement shall serve as the basis to compute the leakage for 24 hours.

If the leakage is at a greater rate than that specified herein, the contractor shall recalk and, if necessary, remake the joints until the leakage shall not exceed the rate specified; if after recalking and examining the entire line, the leakage is in excess of that allowed, the contractor may, with the approval of the engineer, adopt some other method to make the joints watertight and bring the leakage within the prescribed limits. . . . .

The allowable leakage on this line, which contains 157 12-inch flexible joints, 9 12-inch ordinary joints and 7 6-inch ordinary joints between valves, is at the rate of 166.5 gallons in 30 minutes, or 5.5

gallons per minute. The best that was obtained by the contractor during 1916 showed a leakage of approximately three times this allowance.

In May, 1916, the contractor wrote that he would be ready to test the line within a short period. The diver reported about this time that one of the pipes had a split hub. The location of this joint was given as being 75 feet from shore and in 65 to 70 feet of water. The contractor submitted a drawing of a split sleeve which he proposed to place around the split hub, to make the joint water-

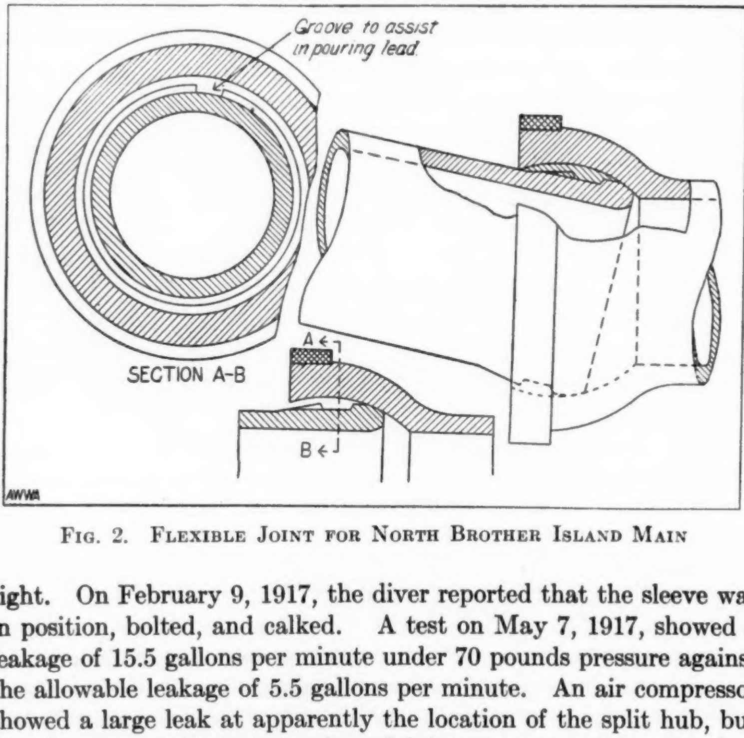


FIG. 2. FLEXIBLE JOINT FOR NORTH BROTHER ISLAND MAIN

tight. On February 9, 1917, the diver reported that the sleeve was in position, bolted, and calked. A test on May 7, 1917, showed a leakage of 15.5 gallons per minute under 70 pounds pressure against the allowable leakage of 5.5 gallons per minute. An air compressor showed a large leak at apparently the location of the split hub, but the diver reported that the sleeved joint was water-tight and that this leak was a new leak about 20 feet beyond the sleeve. He also stated that at the new leak the pipe had taken its maximum deflection, or, as he expressed it, was "iron to iron." Neither one of these statements was borne out by the facts. The diver reported that each time he calked lead into this "iron to iron" joint, the lead blew out again when the pressure was turned on, and he said he

could not make this joint watertight. The contractor claimed that this was a new development for which he was not responsible. It did not appear that the rusting of the joints aided materially in preventing leakage under pressure.

The contract was declared abandoned on June 20, 1917.

The main was placed in service and has been in service up to the present time, except when the line was shut down for testing or repairs. Under an order from the Department of Water Supply, Gas and Electricity, a firm of divers made an examination of the line in July, 1918, and reported that there were eight leaks. One joint approximately 115 feet from the dock was reported to be leaking badly all around.

A contract was let on July 3, 1919, for a lump sum, to complete the work of the abandoned contract. The new contractor attempted to repair the line by use of diver and diver's outfit only, viz.: launch and air pump, but was unsuccessful, and after a month's trial abandoned that method. A floating hoisting derrick was then employed. The line was cut at the Bronx shore, the joints burned out by acetylene burner and the pipe removed for a distance of 130 feet from the edge of the dock. The following lengths of pipe were removed: one 9-foot length, one double-hub piece 2 feet long, four 6-foot lengths and eight 12-foot lengths, a total of 130 feet.

The sixth 12-foot length, 107 feet from shore, was found to have the hub split in three places, the cracks extending from the face of the hub entirely through the length of the hub, figure 3. Lead had been calked into these openings in the face of the hub, but no split sleeve was found. One half of a wrought iron band, 2 inches wide by $\frac{1}{2}$ inch thick, was found tied around the pipe with a piece of rope. The other two pipes removed beyond this did not show any defects, but were removed on account of the previous diver's report that a new leak had developed 20 feet beyond the sleeve. Three more lengths of pipe were lifted out of the water for examination but as no defects appeared they were not burned out.

The pipe was then lashed horizontally to the lighter, the double hub piece and one length of pipe being laid and joints run horizontally. The use of the double hub piece reversed the joints towards the Bronx shore, otherwise it would have been extremely difficult to reconnect the line. The last pipe laid was then held vertically by the derrick and the others allowed to drop slowly into the river. The remainder of the line from here to the shore was laid in the ordi-

nary way. The end of the line was then lifted horizontally and pushed through the cribwork of the dock to be made up to the remaining flexible pipes which were left in the ground. This joint was made horizontally, it being completely exposed at low tide. It might be mentioned here that there are three New York Central Railroad freight tracks, side by side, under which the flexible pipe was laid through the cribwork of the dock. The easterly rail of one of the tracks is within 4 feet of the edge of the dock. The distance

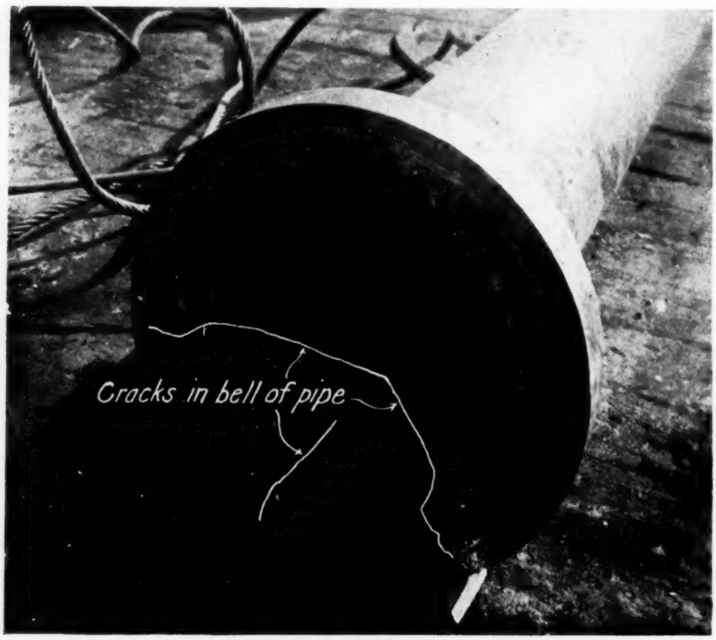


Fig. 3. Cracks in Pipe 107 Feet from Bronx Shore

from the edge of the dock to the 12-inch valve is 83 feet, and all except 3 or 4 feet is flexible-jointed pipe.

An interesting occurrence took place here. When the contractor was ready to lay his last two pipes, he measured the distance from the end of the last pipe laid and held by the derrick to the end left in the ground, and it appeared that more pipe would be placed in the line than was there originally by approximately 9 feet. When the joints were run, however, and the main outside the dock lowered to the bottom from the derrick, two joints on shore, 18 and 27 feet

from the dock, buckled. These joints were burned out, the extra length of pipe removed, and the remaining end of the pipe moved inland of its own accord to within about a foot of its original position.

The remaining pipe, flexible and ordinary, was taken out and relaid to the 12-inch valve. It was expected that, owing to the frequent raising and lowering of the end of the main near the dock, and the consequent flexing of the joints up and down, the lead would have been compressed in the joint and leakage would occur. An air compressor showed eight leaks close to the dock. Up to this writing a diver (not the one who put on the phantom sleeve), has made seven of these joints watertight. Other leaks appear 150 to 200 feet from the dock. The contract is not yet completed.

Outside of the difficulty at this place, the remainder of the line is in good condition, as evidenced by the fact that it has been emptied of water repeatedly, filled with compressed air to 30 or 40 pounds pressure and a few times to much higher pressures, then emptied of compressed air and filled with water again. Also, the pressure on North Brother Island does not vary materially from the pressure at the Bronx shore, which is about 50 pounds per square inch.

It is evident that a flexible jointed pipe line, properly constructed, is well suited for the purpose of a water supply under conditions like those shown, but it is also evident that a flexible pipe line is not meant to be lifted up and down repeatedly, as this compresses the lead in one position of the joint and in the reverse position this compressed lead does not fill the joint and allows leakage.

The number of hours that a diver can work at a location like this where the tide is strong and sweeping, varies greatly. In winter, with ice in the river, about one-half an hour at each tide is all that can be expected. Divers have at times stayed submerged only 15 minutes at each tide. In good weather, and when the river is calm, two hours at each tide can be utilized. No great difficulty was experienced in keeping the floating derrick steady.

It was found advantageous to cut a groove in the spigot end of the pipe, parallel to its axis, to permit the lead to flow quickly to the circumferential groove around the spigot end. This groove may be rectangular or U-shaped and about 1½ inches wide, as shown in figure 2.

THE NARROWS SIPHON FROM BROOKLYN TO STATEN ISLAND[1]

By John P. Hogan[2]

The Narrows siphon built by the Board of Water Supply of New York City is a 36-inch flexible-joint cast-iron pipe line laid across the entrance to New York Bay from Brooklyn to Staten Island. The minimum depth, except at the approaches, is 60 feet below mean low water, and the maximum depth at the center of the channel is 74 feet. A pressure tunnel to convey the water from Brooklyn to Staten Island was rejected on account of the great cost of construction in comparison with the small amount of water to be delivered, the difficulty of determining all the conditions of the work with the rock at great depths, and the long time necessary to drive such a tunnel even under favorable conditions. A shield-driven tunnel was estimated to cost much more than a pipe line with flexible joints, and the latter was accordingly selected.

The siphon crosses the Narrows, as the entrance to the Bay is called, at a section where the shipping in and out of the Bay is very active, and where there are two anchorage grounds, one for merchant vessels and one for war ships. The government regulations prohibited refilling the pipe trench above an elevation 45 feet below mean low water. The pipe line had to be protected by at least 8 feet of backfill, which made it necessary to place the bottom of the pipe at least 56 feet below mean low water. This great depth rendered work on the bottom so difficult that it was considered preferable to lay the pipe in a continuous line by means of a cradle rather than to make up several lengths at the surface and joint these sections together after they were lowered to the bottom.

The angle of deflection of the joints in laying by means of a cradle was about 5 degrees, enough to destroy the effect of any ordinary calking of the lead in the joints, since the effect of this calking

[1] Read before the New York Section, October 22, 1919. Discussion is requested and should be sent to the Editor.

[2] With Parsons, Klapp, Brinckerhoff & Douglas, 60 Wall Street, New York.

rarely extends farther than about $\frac{3}{4}$ inch into the lead, while the maximum movement of the spigot inside the hub was about 2 inches. If the calking were done in the usual way before the pipe began its movement down the cradle, the effect of the bending of the joint would be to loosen the lead so that after the pipe reached its final position on the bottom it would be necessary to calk the joint again. To do this in such a depth of water would be very difficult. Frequently flexible joint lines which leak very much at low pressures are relatively tight at high pressures, because the tightness of such a joint after flexing is due to the greater resistance of the bell than the spigot to the working pressure.

Experiments were accordingly made to ascertain if it was possible to design a joint which would permit the necessary motion and yet remain tight. It was not possible to find any material which did not shrink in cooling and thus make calkng necessary. Joints calked with lead wool proved tight but were not flexible. It was finally decided to pour the joints in the usual way and then attempt to calk them by forcing in lead pellets under great pressure to compensate for the shrinkage of the lead joint in cooling, estimated at about 10 per cent.

The first experiment was made as indicated in the sketch of Joint 1 in figure 1. Sixteen holes were bored through the bell at equal intervals and then tapped to receive a chrome steel gib screw. The joint was poured with lead in the usual manner. A mixture of flake graphite and anti-friction compound was placed in the holes and forced down by screwing the gib screws. The holes were next filled with cylinders of lead $\frac{1}{2}$ inch in diameter and 1 inch long and the screws again driven down, using a Little David air drill to rotate them. About seven of these little cylinders were used in each hole, after which it was closed by a cast-iron plug. The joint made in this way proved tight after being flexed and it was accordingly decided that it would be practicable to lay the pipe in the manner proposed.

Experiments were next undertaken to find the type of joint of this general pattern which would offer the greatest resistance to longitudinal pull. An ordinary pipe line becomes tight when subjected to a longitudinal strain but the joints will leak when the strain is released. In laying some short subaqueous pipe lines with flexible joints, they have been pulled considerably in laying and the weight or sag of the pipe has been relied upon to keep the line tight.

The Narrows siphon is so long that no reliance could be placed on the sag to keep the joints tight and it was also necessary to provide for temperature stresses. In the first experiment it was found that the lead in the bell did not flow, but was merely displaced by the pellets forced in, giving merely a band of tightness and not a satisfactory contact over the whole face of the bell.

The next experiment to ascertain if it was possible to increase the longitudinal strength of the joint was made with the holes moved

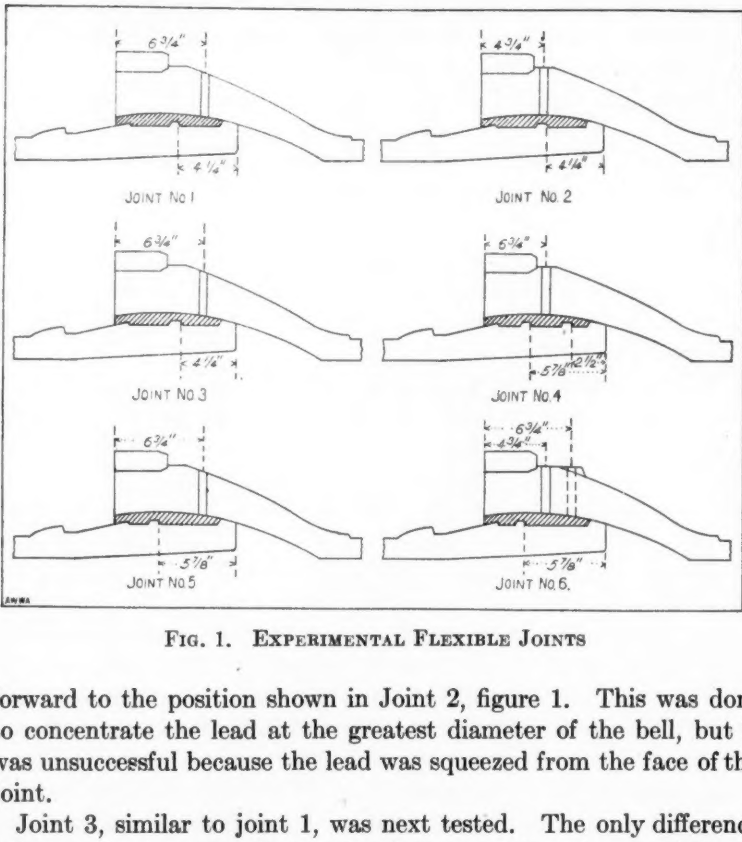


FIG. 1. EXPERIMENTAL FLEXIBLE JOINTS

forward to the position shown in Joint 2, figure 1. This was done to concentrate the lead at the greatest diameter of the bell, but it was unsuccessful because the lead was squeezed from the face of the joint.

Joint 3, similar to joint 1, was next tested. The only difference between the two was that in the latter experiment a much larger quantity of lead was forced into the holes. This did not give the desired results. After a certain amount of lead had been forced in, the introduction of any more drove the spigot out faster than it filled the space in the joint.

Joint 4 was then tried, and was found to have considerable longitudinal strength, but this was unfortunately gained at the expense of flexibility.

Joint 5 was designed to overcome the difficulty just mentioned. It proved on test to have good longitudinal strength and flexibility, but there was a slight leakage between the spigot and lead

Joint 6 was found to overcome all these difficulties, the two sets of gib-screwholes permitting the joint to be thoroughly calked without interfering with either flexibility or longitudinal strength. The details of the joint as finally worked out are shown in figure 2 There

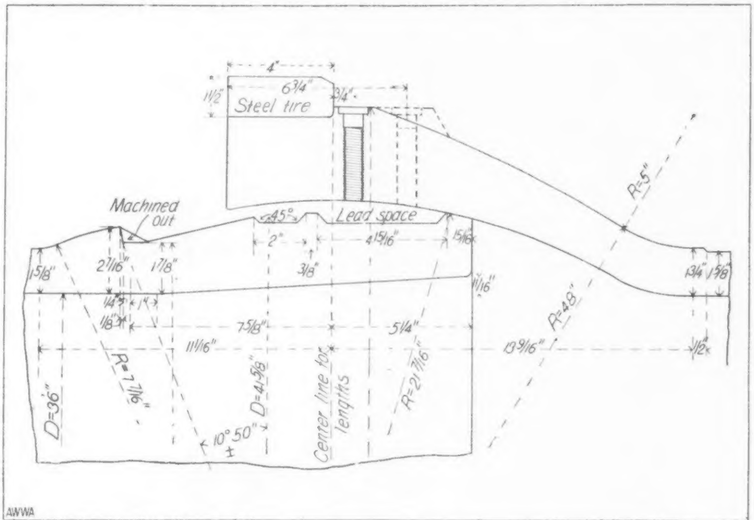


FIG. 2. FLEXIBLE JOINT USED ON NARROWS SIPHON

were two rows of screw holes, each row having 16 holes; the holes in the two rows were staggered.

The joint was made on the deck of a scow as shown in figure 3. The inside of the bell was first coated with graphite. After the spigot of the next length of pipe had been centered in place, the lead was poured into the joint, about 280 pounds being used. Three cylinders of lead, each $\frac{9}{16}$ inch in diameter and $\frac{3}{4}$ inch long, were forced by compressed air into each of the back holes and one into each of the front holes. Grease to which 10 per cent of graphite had been added was forced into each hole and the gib screws driven down. About 24 pounds of pellets were used in a joint. The joint

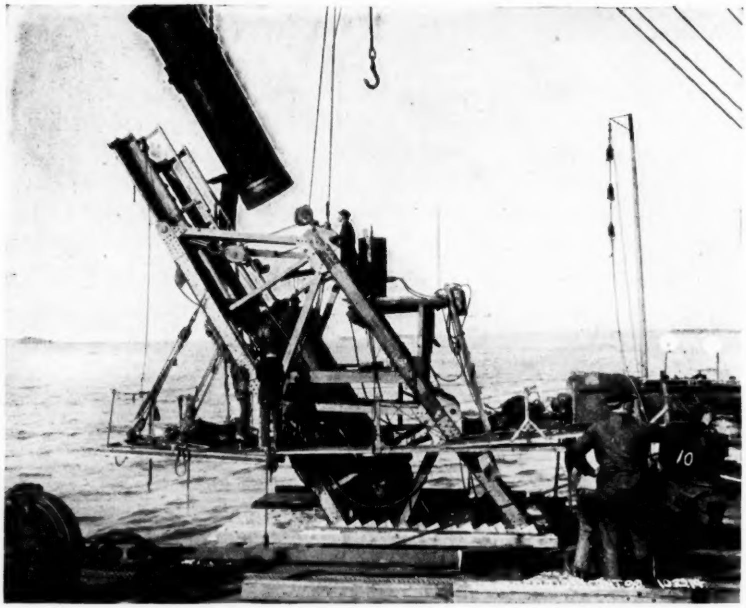


FIG. 3. MAKING UP A JOINT

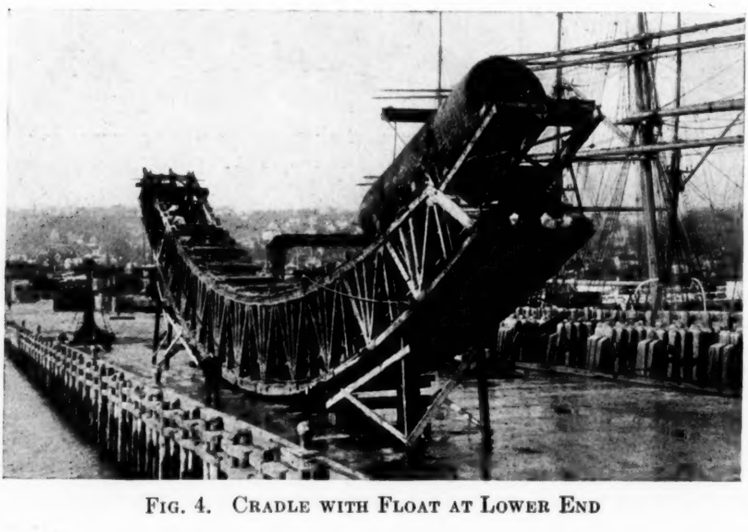


FIG. 4. CRADLE WITH FLOAT AT LOWER END

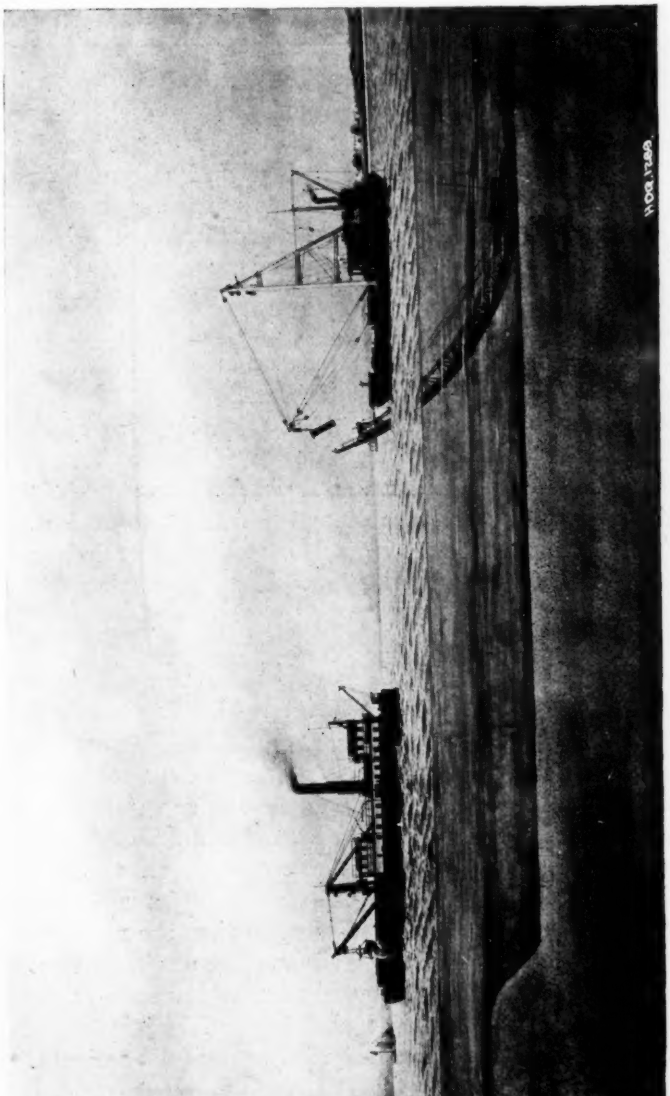


Fig. 5. Dredging Trench and Laying Pipe for the Narrows Siphon

was then deflected 5 degrees and tested under a hydraulic pressure of 100 pounds per square inch before it was launched.

The pipe-laying scow was 40 by 125 feet with a 70-ton derrick. It was held in position by ten anchors. Originally the cradle was swung from this derrick over the side of the scow, but later it was carried by cables running over a trunnion at one end. The cradle was built of structural steel, as shown in figure 4. It was 168 feet long, 8 feet wide and 10 feet high, and weighed nearly 60 tons.

The pipe was so tight when laid that no satisfactory measurement of the leakage could be obtained. The only trouble experienced was in the early stages, when the pipe was tested under a pressure of 120 pounds to the square inch with one end free in the cradle. One of the joints just beyond the end of the cradle buckled and was straightened and replaced by a harness and recalked with lead wool by divers.

In dredging the trench about 450,000 cubic yards of material were removed, the maximum depth of trench being about 38 feet. In general the material, fine sand and silt, stood on slopes of 2 horizontal to 1 vertical, with a bottom width of 20 to 30 feet. The trench was smoothed before laying by towing up and down a V-shaped drag similar to a snow plow. The pipe was covered with from 8 to 10 feet of refill.

Soundings taken one year after completion indicated that the unfilled trench above the refill is moving upstream, but there is no scouring at the bottom into the cover refill. The trench did not seem to be filling up at that time.

The whole 10,000 feet of pipe line was laid in two working seasons. Figure 5 shows the manner in which the dredge was kept working ahead of derrick scow, and the trench was backfilled close to the end of the cradle. At the end of the first season's work the cradle was pulled out from under the pipe and at the beginning of the next season's work the cradle was launched so that the rear end came within about 2 feet of the pipe already in place on the bottom. The pipe was then made up and allowed to slide down the cradle until it entered the bell of the last length laid. This joint was drawn together by a harness and calked with lead wool by divers. The harness was left in place.

THE BAYONNE WATER PIPE CROSSING UNDER THE HACKENSACK RIVER[1]

By Francis H. Sherrerd[2]

To allow for the expansion of The Federal Shipbuilding Company and also for the delivery of an adequate water supply to the City of Bayonne, N. J., through a substantially built system, a contract to lay two lines of 30-inch land pipe about 3300 feet long and two lines of 30-inch flexible joint subaqueous pipe about 1800 feet long, was entered into to replace unsafe lines which had been in service running through the Federal Shipbuilding Company's property and crossing the Hackensack River with two 18-inch flexible joint lines. Some of the work is in Kearney and some in Jersey City and parallels the Lincoln Highway.

The submarine work was particularly interesting and finished in good time by The Snare & Triest Company, contractors, under the direction of M. R. Sherrerd, Consulting Engineer. Class D pipe with a modified Ward or Metropolitan type joint was used, figure 1. The spigot end of the pipe is ball-shaped, machined to a true surface and limited to within $\frac{1}{32}$ inch of the prescribed diameter with a slight rise to the barrel of the pipe at the inner end to act as a bumper in case of an accidental deflecting of the pipe to a greater angle than the 10 degrees allowed in the specifications.

The bell end is a socket with a ring machined to the same shape as the ball 6 inches in from the face of the bell and about $\frac{3}{4}$ inch wide, straight on the inner side and sloping on the outer. Two grooves were cast in for the lead. A steel tire was shrunk on the bell end to give greater strength. It was thought best to use this type of joint as, after calking, the lead remains in the socket end and the ball moves in it and requires less care in lining up the pipe before making each joint and also makes it much easier to calk up all leaky joints.

[1] Read before the New York Section, October 22, 1919. Discussion of this paper is invited and should be sent to the Editor.

[2] Engineer in charge, Hackensack River Crossing, Bayonne Supply Mains.

The average amount of lead used per joint was 155 pounds, and the depth of joint about $5\frac{1}{2}$ inches, as one strand of yarn was used.

Great care was used in handling the pipe to prevent scarring the balls. The machined surfaces were carefully scraped and cleaned

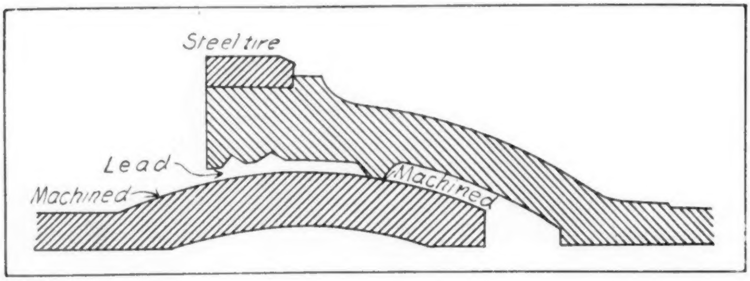


Fig. 1. Flexible Joint on Pipe Across the Hackensack River

Fig. 2. The Beginning of the Subaqueous Pipe Laying

and oiled before laying. Any sandholes or defects which passed the inspection at the foundry were repaired by boring small holes, larger at the bottom than top, and filling with babbitt metal.

The floating equipment consisted of two large derrick scows carrying an air compressor and pumps, one deck scow, one large launch and a large cradle from which the pipe was laid, figure 2.

The cradle was built of timber, firmly braced and bolted, with a curved track to carry the pipe. The track rested on eight 12-foot members, chords of an arc of a circle of 86 feet radius, each segment being 8 degrees. The long chord at the top of the cradle was about 91 feet. The width of the cradle over all was 16 feet, and that of the tracks about 2 feet 6 inches.

The cradle was swung between one derrick scow and the deck scow in such a manner as to allow easy raising and lowering to prevent too great deflection of the pipe at the bottom of the cradle, caused by the motion of the tide, and also to remain within the limit of deflection on the slopes on each side of the river.

The plans required the laying of the two lines on 20-foot centers and a trench 40 feet wide on the bottom was dredged at a depth of 32 feet below mean low water between pierhead lines. From the pierhead line to the shore on one side of the river an easy slope of approximately 10 to 1 was possible, but on the other it was necessary to make it about 4 to 1. As this was at the far end of the work, it was quite difficult to carry the cradle at the right angle to keep the foot of it so that the slope would be tangent to it. All mud was removed and replaced with sand and clay and the uneven bottom smoothed out within reasonable limits. About 100,000 yards of material was dredged.

One derrick scow was used to load pipe at the dock and to assist in the handling of the cradle. The two other scows firmly lashed and carrying the cradle were anchored in such a way as to carry the center of the cradle in line with rangers set on the shore.

One length of pipe at the start was made fast in an anchorage of piles on the shore. Next two sets of two lengths each were made up on the deck of a scow and lowered in line. Then the joints were poured and calked and the whole laid on the lower end of the cradle, the upper end of the cradle having been hoisted high in the air. After that each length was laid separately in the cradle and lashed securely so that the whole might not slide. The bell end of the last length laid was blocked off the curved track so that the spigot end of the one to be laid could be lowered in, leaving the two in nearly a straight line. Care was taken to see that the last joint made was not deflected too much. The joint was then made and calked

hard, the block taken out and joint broken by lowering it into the curved track again. The lashing on the pipe was then loosened and scows and cradle moved back in line by tightening and loosening anchor lines.

In going up the slope on the far side of the river, more trouble from leaky joints was expected owing to the natural pushing of the ball into the socket and possible pushing away from the lead, but by careful calking this was overcome and only three or four leaks of any consequence resulted, although as a result of the hard calking it was much more difficult to break the joints.

On the first line the use of the cradle was stopped at about six lengths from shore and it was pulled out with an end and side motion, moving the pipe, without intention, to the limit of deflection in two joints, which, in combination with the action of the tide when the pipe was suspended from a derrick, caused them to leak and made it necessary to calk them again. The last three lengths laid were then suspended from one derrick scow and the remaining lengths laid from the other.

At the end of the laying of the second line, the cradle was unbolted in the middle and taken out in two pieces so that the pipe was not disturbed.

Each day's work was inspected from the inside and any dripping joints or bad bends were noted.

This was done by lowering a man down the pipe from the cradle end and although it required great physical effort proved much more satisfactory than diver's inspection. From the shore ends the pipe on the slope was easily inspected down to the place where water leaking through the bulkheads would make it inconvenient. The shore ends of the pipes were below high water and often the bulkheads were not perfectly water-tight.

It was found easily possible to repair leaks from the inside, but where more than two or three appeared it was cheaper to repair by calking by divers on the outside. It took considerably more than 100 pounds of lead wool to repair a small leak on the inside and on account of cramped quarters and the curved shape of joint took too long a time.

The first line was laid at the rate of 6.8 lengths per day and the second at 7.9. The best day's work was 18 lengths, and a rate of 12 lengths per day could easily have been maintained after organization had it not been for delay in dredging and bad weather.

The force required for laying consisted of three calkers, three riggers, three engineers, four laborers.

The specifications required both air and water tests. Nearly all leaks showed at 10 pounds air pressure. The pressure was finally raised to 70 pounds, but all leaks that showed at 70 also showed at 40.

On the first line, after repairing all visible leaks, the pressure was raised to 72 pounds at 4 p.m. At 8 the next morning it was 61 pounds. On the second line at 3 p.m. the pressure was raised to 70 pounds and at 8 the next morning was 55 pounds, in spite of an air leak in one of the valves.

The water leakage allowed amounted to about 1 cubic foot a minute for 24 hours. The lines were filled with fresh water, although the specifications allowed sea water, and all was sterilized by the addition of hypochlorite in the proportion of two parts available chlorine per 1,000,000. The leakage was so small that the pumps could not be run slowly enough not to exceed the required pressure. In the first line the pressure was raised to 108 pounds at 3.30 p.m. At 5.30 it was still 108 and at 8 the next morning was 91½ pounds. It took 50 cubic feet of water pumped in 11 minutes to bring it back to 108 pounds. On the second line the pressure was raised to 100 pounds and after 1 hour fell to 98 pounds. It took 7 cubic feet of water pumped in 6 minutes to bring it back to 100 pounds. After 20 minutes there was no perceptible loss in pressure.

The pipe is now being covered with a sand blanket 3 feet deep by means of a derrick scow equipped with a hopper and pipe which can be adjusted with a telescope arrangement to fill almost exactly to the required depth. This and the construction of two large concrete blocks over the anchor piles on the shore end will complete the job.

DISCUSSIONS

THE IMPROVEMENT OF RURAL WATER SUPPLIES

The article by Dr. E. G. Birge on "The Rural Water Supply an Integral Part of the Municipal Supply," published in the March, 1920, issue of the JOURNAL, presents a number of suggestions which should be of keen interest to all intelligent citizens, and especially to those who are concerned with the protection of the *reputation* as well as the *character* of municipal water supplies.

Under modern conditions man does not—and with wisdom cannot undertake to—live "unto himself alone." Between any two groups of residents in the United States as widely separated as is geographically possible the bonds of connection are many. What is for the good of one community is for the good of all. This is the case with matters general and it is particularly obvious with matters sanitary. Dr. Birge properly emphasizes that health work to safeguard the citizens of a municipality against typhoid fever should be statewide. It may be added that health work to give to the citizens of any of our large municipalities adequate protection against typhoid fever and other communicable diseases must be nation-wide in scope.

A person contracting typhoid fever infection through drinking water from a well or spring polluted with human excreta in a rural district in Maine or California may travel, within the incubation period of the disease, to some large city in the Mississippi valley and there, either before or after the development of definite symptoms of typhoid fever, constitute the source of extensive municipal infection. Though in such instance the infection be spread through the media of food, fingers and flies, the epidemic is likely to excite popular suspicion against the municipal water supply and cause the water works officials serious embarrassment. Many of our large cities obtain their water supplies from rivers or lakes whose sheds drain rural districts in two or more states. The excretal pollution from rural communities of such water courses is a matter of direct concern to those responsible for the wholesomeness of municipal water supplies. The control of the pollution of interstate water courses, to be equitable and adequate, will have to be exercised by some interstate, or national, authority.

In the field of rural sanitation with its vitally important intra and interstate bearing on urban, as well as rural, health, it appears clear that the national government along with the state governments has a definite responsibility and a large opportunity. Since 1914 the U. S. Public Health Service has been engaged in coöperation with state and local health authorities in work for the advancement of rural sanitation. This work has been conducted on as extensive a scale as the remarkably conservative appropriations by Congress for the purpose have made possible. One of the first steps in the work was a complete house-to-house sanitary survey of counties fairly representative of extensive rural districts in different parts of the country—north, east, south and west.

Eighteen counties distributed in sixteen states were surveyed. The findings and the results of the county sanitary surveys are presented in Public Health Bulletin No. 94. At more than 60 per cent of the thousands of farm homes surveyed, the water supplies used for drinking and culinary purposes were found to be obviously, and more or less grossly, polluted with fecal matter. Less than 2 per cent of the sixty-odd thousand country homes visited were equipped with sanitary toilets. Under such conditions in our rural communities generally, it is not surprising that the drift of typhoid fever and other excretal infections is now from the rural district to the city rather than from the city to the rural district, as was the case before the days of extensive installations of adequate municipal water purification systems. From the studies made by the Public Health Service, the important practical conclusion reached was that with a reasonably adequate local health force on the work rural sanitation advancement is feasible. In line with this conclusion, the present program of the Public Health Service is to coöperate with states, counties, townships and municipalities in the development and maintenance of efficient local health organizations to look after the business of public health in rural districts. The purpose of this coöperation is to effect in different parts of the country practical demonstrations of the value of rural health work and thereby to stimulate popular interest toward having state, county, township and municipal governments do their proper parts in the vitally important field of nation-wide rural sanitation.

For the average rural county a health organization to be reasonably adequate should consist of a whole-time health officer, one whole-time health nurse and one whole-time sanitary inspector.

The services of such a country health force can be obtained for about $8,000.00 a year. For the county adopted as a national unit of the coöperative demonstration work in rural health promotion, such a budget may be furnished as follows: $2000 from the U. S. Public Health Service Fund, $2000 from the State Board of Health fund and $4000 from a fund appropriated by the county authorities.

Under the provisions of the Congressional appropriation, the U. S. Public Health Service cannot enter into the demonstration work in a community unless the state, the county, the township or the municipality in which the community is located, separately or together, agree to bear at least one half the expense of the coöperative demonstration work. As a rule more than three-fourths of the expense is met with funds from state and local sources. The head of the demonstration work in the county is appointed by the proper county authorities as county health officer. He is given a status in the state health department, usually that of deputy state health officer. He is also given a status of Field Agent in the U. S. Public Health Service. His qualifications for the position must appear satisfactory to all three coöperating agencies. Thus the county authorities are relieved of any local political embarrassment in declining to appoint one who does not appear qualified, and efficiency of service is promoted. The general plan of the work is agreed upon by authorized representatives of the coöperating agencies. Monthly reports of progress are submitted to the proper offices of the county, the state and the national government. The county is visited from time to time by officers of the State Board of Health and of the U. S. Public Health Service, who inspect the work and advise with the county health officer. The officers detailed for the inspection of the work in the county units are experienced in rural sanitation business and thereby are enabled to give helpful practical suggestions to the heads of local units. Such supervision is obviously advantageous. With the relatively large number of individual property owners who have to see the sense in making the investments before sanitary progress in the rural district can be accomplished, the factors of personal equation are even more important in the rural health force than in the city health force operating under municipal ordinances to carry out mass sanitary measures. The inspecting officers give especial attention to the factors of personal equation, and by presenting the results of the work in the

other demonstration counties stimulate the unit in each county to do its best.

The results of this coöperative demonstration work in rural sanitation have been highly encouraging. In every one of the demonstration counties, marked sanitary improvements have been accomplished within the first few months of operation. Villages and towns replace grossly polluted water supplies with clean water supplies, and grossly insanitary systems of excreta disposal with sanitary systems. In some of the counties radical sanitary improvements with respect to water supplies and excreta disposal have been made at over 50 per cent of the strictly rural houses within the first year of activity of the coöperative health organization. Such sanitary progress in our rural districts means much to the health protection of our rural population and also, as Dr. Birge points out, to the health protection of our urban population.

Work for the prevention of disease and the promotion of health appears to be one of the most logical and, surely, one of the most important functions of democratic government. The sanitary conditions of any locality in the United States have a bearing on the health interests of the locality, of the state and of the nation, and, therefore, should be of concern to the local, the state and the national governments.

The extent to which our governmental agencies will participate in public health business will depend upon popular demand. The critical need for rural sanitation advancement is manifest in all parts of our country—north, east, south and west—including especially our most prosperous states. The urban population has due cause to be concerned seriously about the lack of rural sanitation. Those responsible for the safeguarding of municipal water supplies have especial cause to try to stimulate a reasonable and proper popular demand for much greater activity by governmental and other agencies in the national field of work for rural sanitation advancement.

L. L. Lumsden.[1]

[1]Surgeon, U. S. Public Health Service, Washington.

GROUT AND LEAD WOOL FOR CRACKS IN CONCRETE RESERVOIRS

Referring to the request in the January JOURNAL, for experiences as to methods of stopping leaks due to cracks in the bottom of concrete lined reservoirs, the writer submits the following:

The organizations with which the writer is connected have a number of concrete lined reservoirs, several of which have shown leakage at various times. In no case has the leakage been so great as to constitute a menace to the reservoir and stopping the leakage was attempted entirely as a preventative measure.

The method suggested by D. A. Reed[2] has not been used, owing to the necessity for maintaining a fire in order to heat the asphaltum.

One of the most successful methods has been to open the crack by chipping and placing sections of 1½ inch pipe at proper intervals. The crack between the pipes is filled with a rich, strong grout and, after this has thoroughly set, neat cement grout is pumped through the pipes to refusal, taking care that the pressure does not approach that which would blow out the grout placed in the crack or lift the concrete. A small, ball-valve, hand pump, such as is used for spraying fruit trees, has been used very satisfactorily for this purpose.

Where the cracks are very small and there is not much current in the reservoir, excellent results have been secured by inducing coagulation in these cracks. In several cases where the water was turbid, alum, sown broadcast, has been sufficient; in other cases it has been necessary to use lime to raise the alkalinity and also to introduce a mixture to supply the material which is to be coagulated in the cracks.

In the case of small, concrete chambers, hemp and lead wool[3] have been calked into the cracks. Very satisfactory results were secured by this method in a concrete penstock, serving two small water turbines.

CHARLES HAYDOCK.[4]

[2] This method is to cut a groove, half an inch wide, and about three-fourths of an inch deep, along the crack with a chisel, and then calk the groove with hemp and asphaltum.

[3] Capt. Paul Hansen has also reported the successful calking of fine cracks with lead wool, without much preliminary preparation of the cracks.

[4] Engineer, Mountain Water Supply Company, Philadelphia, Pa.

LEAD WOOL FOR CALKING CRACKS IN CONCRETE RESERVOIRS

The writer has had considerable experience in stopping leaks in concrete reservoirs, both in the bottoms and in the walls. Some of these leaks were caused by porous concrete of a very limited extent, while others were caused by shrinkage and settlement cracks.

In order to stop these leaks many schemes have been tried but the one that has given a great deal of satisfaction is as follows: The cracked or honey-combed portion is first cleaned, by means of chisels, of all loose and broken material. Great care is taken to do the job in a first-class manner. In case the crack is very small, then it has been the writer's practice to enlarge this crack to a depth of about 1 or $1\frac{1}{2}$ inches, making the enlargement in the form of a V. After the concrete has been prepared in the above manner, lead wool was driven into the crack or porous portion of the concrete by means of a suitable calking iron, very much in the same manner that the lead is calked in the joints of a cast iron pipe, using only a small portion of the lead wool at a time and continuing the process until the crack is completely filled even with the surface of the concrete on the two sides. Care must be exercised to see that the lead wool is well driven into place and forms a homogeneous mass instead of merely being shoved in haphazardly. When finished the crack appears exactly like a calked joint on a hub and spigot cast iron pipe. This method has been used on both inside and outside of structures so that the pressure may tend to either hold the lead wool in place or to push it out of the crack. Although this method of stopping leaks has been used for the last six or seven years no job has had to be done over a second time. Of course, unless the concrete is dense and of a good mixture the writer would not recommend this practice but with a good 1:2:4 mixture, properly mixed and placed, it has given a great deal of satisfaction at a very reasonable cost.

W. N. Jones.[5]

ASPHALT AND FELT MEMBRANE FOR CONCRETE RESERVOIR LININGS

In the Comments in the January issue of the Journal there is an invitation to discuss how leaks due to cracks in the bottom of a concrete reservoir may be stopped. It is said that "Confession

[5] Chief Engineer, Design and Construction, Filtration Plant, Minneapolis, Minn.

is good for the soul," hence the following. The writer has had a very limited experience in repairing temperature or other irregular cracks in reservoir linings; but he has attempted to waterproof the so-called expansion joints usually employed in the construction of reservoir linings of any considerable area. His experience has taught him chiefly, however, "how not to do it."

In 1894 there were built for the water works of the city in which the writer lives, three small concrete-lined reservoirs of 12, 16 and 17 million gallons capacity and 30 to 49 feet maximum depth. The lining for these reservoirs was laid in alternate sections, 12 to 18 feet in width, extending up and down the slopes and across the reservoir bottoms. When the alternate sections were laid a beveled board was placed between adjacent slabs, which was removed later, leaving a tapering space about ½ inch wide on top and about 3 inches deep. This space was then filled with asphalt mastic and the entire reservoir surface covered with a mopped coat of hot asphalt.

The excavation for the smaller of these reservoirs was entirely in cement gravel and there has never been any appreciable leakage therefrom, probably due, principally, to the character of the earth foundation.

The linings of the two larger reservoirs were wrecked by a land slide before they had been in use for any considerable period, but so far as observed the water proofing of the joints was not a success.

In 1904 these reservoirs were relined under the direction of the writer. Two courses of concrete were laid with a membrane between made of hydrex felt coated with asphalt. The bottom course of concrete was laid without joints, but for the top course expansion joints were provided every 12 to 16 feet, extending up and down the slopes and on the bottom. Between the slabs two thicknesses of felt coated with asphalt were placed, against which the concrete was tamped, to provide for possible expansion or contraction of the lining.

A thorough system of under drains, leading to a sump outside of the dam forming one end of the basin, has enabled the engineers to observe the volume of leakage through the lining, which might occur. This, however, has been of small amount, in fact a negligible quantity.

Six years later the writer, as chief engineer, designed and built two other concrete lined reservoirs, of 50 and 75 million gallons capacity, and 30 feet maximum depth. The linings consisted of a

single layer of concrete, 5 to 10 inches in thickness, laid in sections 12 to 15 feet in width, extending up and down the slopes and across the bottom, the bottom sections varying from 20 to 40 feet in length. Under all joints a 5 by 9-inch concrete beam was built, faced with tarred felt coated with asphalt, the vertical joints between the slabs being faced with a similar layer of felt and asphalt. The entire surface of the concrete lining was covered with a well troweled finish coat composed of one volume of cement to two volumes of sand.

From an elaborate system of tile underdrains, centering in the gate chamber, a close measurement can be made of the volume of underdrainage due to defects in the lining, joints as well as the body of the concrete. After a trial of a few months the leakage was found to be excessive and subsequently an attempt was made to correct the difficulty by a treatment of the joints between the concrete slabs by applying to the surface of the lining a strip of burlap 6 inches wide with top and bottom heavily coated with asphalt. A few irregular cracks in the body of the lining were treated in a similar manner.

The volume of the leakage from these reservoirs still continues to be excessive and late examinations show that the burlap and asphalt treatment of the joints is defective, the burlap not adhering properly and the asphalt cracking in places along the edges of the burlap strip. The engineers now in charge plan additional repair work on these linings in the near future.

The experience of the writer, therefore, seems to point to the conclusion that for the effective waterproofing of a concrete lining for reservoirs, the use of a membrane of felt and asphalt has superior advantages and will insure thorough waterproofness. In the event such a membrane is used the presence of temperature or other cracks in the surface of the concrete is of minor importance. However, the matter of cost is often a controlling factor which must be considered.

D. D. CLARKE.[6]

INDEX NUMBERS AND SCORING OF WATER SUPPLIES

The writer wishes to state that his discussion of Mr. Wolman's paper on this subject in the JOURNAL of September, 1919, will deal largely with the adaptability of the index number suggested in this

[6] Consulting Engineer, Portland, Ore.

paper to the state sanitary control of water supplies. The writer has been very much interested in this paper since it suggests another method of comparing the sanitary quality of water supplies. It is apparent that the author thoroughly appreciates the difficulties attending the standardization of water supply control either by scoring or by index numbers. In the paper under discussion, he has attempted to eliminate certain fundamental factors which influence the safety of a water supply and has confined his discussion to the analytical control so far as it may relate to establishing index numbers. The application of the theory of probabilities for the purpose of determining an index number on water purification plant operation is most interesting. This mathematical theory has been applied to many other problems and has met with success in those instances where the proper basic data are available to justify its application. Assuming that the basic data given in the example contained in this paper, are sufficient to justify its application for this purpose, it provides a method of graphic comparison of the bacteriological results of water supplies which offers promise.

The use of the simplified index number by a state board of health for comparing the efficiency of water purification plants in a state such as Minnesota is to be questioned. It would appear to offer promise for the comparison of analytical results on some of the larger purification plants throughout the country that are properly constructed and under competent analytical supervision. It would be unfair to use the index method to draw comparisons on the efficiency of operation of plants in a given state unless the number of determinations was sufficient to justify the application of the theory of probabilities for this purpose, and a similar number of analytical determinations had been made during a given length of time on each plant and under similar operating conditions. Unfortunately, in the State of Minnesota, the number of bacteriological examinations made in connection with the operation of water purification plants varies widely, which would make it impossible to compute comparative index numbers on a fair basis. The writer feels that the variation in analytical methods, and especially, in the technique used at the various laboratories throughout a given state, might give occasion for concern when the results were being considered for comparison. The writer cannot be quite reconciled to depending exclusively on the analytical results when a comparison is made of one plant with another. The question of construc-

tion, operation and personnel is so fundamentally involved in the safety of the supply from a given water purification plant that comparison based entirely on analytical results might be very misleading.

As one simple example of faulty construction, it might be assumed that the filtration plant in question was provided with a by-pass, maintained for emergency purposes, through which water could be discharged around the plant and into the distribution system without treatment. It is a well-known fact that this defect in construction has already caused at least one typhoid fever epidemic. Such a defect is a potential danger which might not be indicated by analytical results. It would be unfair to give such a plant the same index number, so far as the safety of its effluent is concerned, as another plant that did not have such a defect in construction. Many examples could be given of faulty construction and possibly some of careless operation that might not be shown in the analytical findings and which would constitute definite hazards against the water supply. The writer feels that when comparisons are to be made of the safety of certain water supplies, the location, construction, operation and analytical results must be given consideration, otherwise a wrong opinion may result.

The index number system presented in this paper presents a new line of thought for further study, but the writer is of the opinion that any system that is devised for comparing the safety of water supplies should give recognition to all the important factors concerned.

H. A. Whittaker.[7]

[7] Director, Division of Sanitation, Minnesota State Board of Health, Minneapolis, Minn.

SOCIETY AFFAIRS

SPECIAL TRAIN FOR MONTREAL CONVENTION

The Transportation Committee of the Water Works Manufacturers Association has arranged for a special train for the Montreal Convention, which will leave the Grand Central Terminal at New York on 9.30 a. m., June 20, reaching Montreal at 10 p. m. the same day. The railroad fare, including tax, is $12.78, seat $2.70, drawing room $9.72. Applications for reservations should be sent to the Chairman of the Committee, Walter H. Van Winkle, 30 Church Street, New York, N. Y.

4-STATES SECTION

The first meeting of the 4-States Section since the World War was held at the Hotel Bellevue-Stratford, Philadelphia, on April 16, 1920, with an attendance of about 60, much less than was expected because the railroad walkout interfered with transportation seriously. Charles R. Wood, Secretary of the Section, presided, and informal talks were made by President Davis on the water problems of Philadelphia; by J. Waldo Smith on the necessity of beginning at once investigations for a new water supply for New York; by John C. Trautwine on the value of water works; by Berkman C. Little on the water works fraternity; and by J. M. Goodell on the value of the work that can be done by the Sections in developing public appreciation of the importance of water works. The paper of the meeting was read by J. W. Ledoux on "Some Observations Concerning Public Service Commissions."

ILLINOIS SECTION

The twelfth annual meeting of the Illinois Section was held at the University of Illinois, Urbana, Ill., on March 25 and 26. The meeting was welcomed on the morning of March 25 by Prof. A. N. Talbot. On that day there were two meetings for business and papers and, in the evening, the annual dinner at which the attendance was 47. On the following day there was a session for the

presentation of papers and a visit to the University buildings. The list of papers was as follows:

"Public Water Supplies in Illinois," by A. A. Brensky.

"Some Methods for the Location of Leaks in Water Mains," by H. E. Babbitt.

"Rational Method of Developing Shallow Ground-Water Supply," by W. D. P. Warren.

"The High Cost of Money to Public Utilities," by Dow R. Gwinn.

"Pre-War and Present Reproduction Cost of Water Works," by L. R. Howson.

"Steam Power Plants for Pumping Stations," by P. J. Kiefer.

"Internal Combustion Engines," by G. A. Goodenough.

"Economy Resulting from the Use of Variable-Speed Induction Motors for Driving Centrifugal Pumps," by M. L. Enger and W. J. Putnam.

"The University of Illinois and the Engineering Experiment Station," by A. N. Talbot.

"Benefit of the Application of Chemistry in the Operation of Water Works Plants," by K. M. Holaday.

"The Value of Bacterial Tests for Potable Water," by M. F. Stein.

"An Outbreak of Dysentery and Typhoid Fever at Bloomington," by M. C. Sjoblom.

"The National Board of Fire Underwriters," by C. Goldsmith.

"Odors and Tastes in Water at Mt. Vernon," by E. Bartow, E. Greenfield and B. Feuer.

"Odors and Tastes in Water at Danville," by E. Bartow, H. M. Ely and R. E. Greenfield.

"Stream Pollution," by Langdon Pearse.

"Protection of Water Supplies by Purification of Sewage," by H. B. Hommon.

"Water and Sewage Purification," by W. J. Allen.

The following officers for the next year were elected: Chairman, F. C. Amsbary, Champaign, Ill.; vice-chairman, John W. Alvord, Chicago, Ill.; trustee, Henry Ringness, Peoria; treasurer, H. E. Keeler, Chicago.

The chairman appointed C. B. Burdick, H. M. Ely, and W. D. Gerber a committee on resolutions, to which was referred a letter from President Carleton E. Davis requesting data as given in the section secretary's report on March 25.

There were 31 active members and representatives of six associate members at the meeting.

TOTAL CONTRIBUTIONS RECEIVED TO MARCH 1, 1920, TO ELECTROLYSIS INVESTIGATION FUND

Cattlettsburg, Kenova & Ceredo Water Co.	$10.00
City of Meadville, Pa.	10.00
Champaign & Urbana Water Co.	25.00
Richmond, Ind., City Water Works	50.00
Portland, Me., Water District	50.00
York, Pa., Water Co.	10.00
J. Waldo Smith	10.00
Quincy, Ill., Water Works Commission	10.00
Kitchener, Ont., Water Commission	5.00
City of Colorado Springs, Colo.	50.00
Acquackononk Water Co., Passaic, N. J.	50.00
Passaic Water Co., Paterson, N. J.	50.00
New Haven Water Co., New Haven, Conn.	300.00
Hackensack Water Co., Weehawken, N. J.	100.00
Davenport Water Co., Davenport, Iowa	100.00
Baltimore County Water & Electric Co.	100.00
Elmira, N. Y., Water Board	10.00
Stamford Water Co., Stamford, Conn.	250.00
Cortland, N. Y., Water Board	25.00
Charleston, S. C., Commissioners Public Works	25.00
Vinton-Roanoke Water Co., Roanoke, Va.	5.00
Tampa Water Works, Tampa, Fla.	50.00
Ansonia Water Co., Ansonia, Conn.	25.00
Newport News Light & Water Co., Newport News, Va.	50.00
Norristown Insurance & Water Co., Norristown, Pa.	10.00
City of Baltimore, Md.	200.00
Board of Water Commissioners, Glens Falls, N. Y.	10.00
Bureau of Water Supply, Troy, N. Y.	100.00
Kansas City, Mo., Water Department	50.00
Biddeford & Saco Water Co., Biddeford, Me.	25.00
York County Water Co., Kennebunk, Me.	10.00
Rensselaer Water Co., Rensselaer, N. Y.	10.00
Springfield City Water Co., Springfield, Me.	25.00
Bureau of Water, Rochester, N. Y.	200.00
Board of Water Commissioners, East Orange, N. J.	100.00
Lexington Water Works, Lexington, Ky.	25.00
Clear Springs Water Co., Bethlehem, Pa.	25.00
Queens County Water Co., Far Rockaway, N. Y.	50.00
Birmingham Water Co., Derby, Conn.	25.00
Total	$2235.00
Disbursements	532.68
Balance	$1702.32

The total sum desired is $3000. Further contributions are requested and should be sent to the Association's Treasurer, James M. Caird, 271 River Street, Troy, N. Y.

NEW YORK SECTION

The New York Section met at the Hotel McAlpin, New York, on February 18 to discuss the subject of water waste control. The chairman of the Section, Morris R. Sherrerd, presided and those taking part in the discussion were: D. W. French, George C. Andrews, A. W. Cuddeback, W. W. Brush, F. B. Nelson, H. T. Havill, F. E. Beck, Wm. A. McCaffrey, F. T. Kemble and Dr. Frank E. Hale.

During the winter the Section has inaugurated a service to water works men which is being watched with interest. All members of the Section are invited to send to the Secretary, Edward S. Cole, requests for information about problems which have arisen in their work, where a knowledge of experience at other water works may be helpful. These requests are submitted to members who are believed to have the desired information, Mr. Cole's office thus acting as a bureau to bring the members together for an interchange of information.

ADDITIONS TO THE MEMBERSHIP

Active Members

Thomas Francis Bowe, Consulting Engineer, 95 William Street, New York, N. Y.

Otto E. Brownell, Civil Engineer, 900 Palace Building, Minneapolis, Minn.

William C. Buck, Consulting Engineer, 1245 West Minnehaha Parkway, Minneapolis, Minn.

C. I. Clarke, Meter Department, Water Bureau, 2 Elizabeth Street, Ottawa, Canada.

Frank A. Connolly, Director Water Department, 55 Remsen Avenue, New Brunswick, N. J.

Alton A. Cook, Chemist, Filtration Plant, 422 Philippi Street, Clarksburg, W. Va.

Avery Z. Crounse, Manager Sanitor Construction Company, 4323 Dupont Avenue South, Minneapolis, Minn.

Thorn Dickinson, Civil Engineer, Bismarck, N. Dak.

James W. D. Farrell, Assistant Superintendent Water Works, 1333 Fifteenth Street, Regina, Sask., Canada.

Franklin J. Gill, Superintendent Water, Light & Heat, Iron Mountain, Mich.

Timothy W. Good, Superintendent Water Works, Cambridge, Mass.

Edwin M. Grime, Superintendent Bridges and Buildings, Northern Pacific Railway, Dilworth, Minn.

John A. Hall, Civil Engineer, Box 407, Devils Lake, N. Dak.

J. G. Hazlehurst, Captain, Q. M., Construction Division, Water Supply Section, Washington, D. C.

Leigh I. Holdredge, Sanitary Engineer with Wallace & Tiernan Company, 1035 Commercial Trust Building, Philadelphia, Pa.

Andrew M. Jensen, Civil Engineer, 18 Patterson Block, Fresno, Calif.

B. J. T. Jeup, Chief Engineer, Indianapolis Water Company, 113 Monument Circle, Indianapolis, Ind.

Clarence Edward Keefer, Assistant Designing Engineer, 235 North Stricker Street, Baltimore, Md.

H. A. McConville, Engineering Inspector, Bureau of Water, 1383 Grand Avenue, St. Paul, Minn.

John William McKay, Borough Engineer, Department of Water Supply, Gas and Electricity, 170 College Avenue, Borough of Richmond, New York, N. Y.

C. F. Malven, City Engineer, Winner, S. Dak.

L. B. Mangun, Chemist in Charge Water Purification, Kansas City, Kan.

Isador W. Mendelsohn, Sanitary Engineer, State Board of Health, 915 Belmont Avenue, Grand Forks, N. Dak.

Robert Mullin, Box 148, Buhl, Minn.

Michael J. O'Hara, Superintendent Public Works, City Hall, Hudson, N. Y.

Sol Pincus, Associate Sanitary Engineer, U. S. Public Health Service, Washington, D. C.

Armando C. Pradas, Engineer in Charge Paving and Sewerage, Camaguey, Cuba.

John L. Radcliffe, Superintendent of Filtration, 663 Madison Avenue, Elizabeth, N. J.

James R. Rubey, City Engineer, Ely, Minn.

Frederic Antes Snyder, Engineer, Commonwealth Water Company, Summit, N. J.

Thomas R. Seabrooke, Chemist, J. B. Clow & Sons, 445 McKnight Building, Minneapolis, Minn.

Albert L. Solleder, Engineer New York Continental Jewell Filtration Company, Nutley, N. J.

W. B. Stevenson, Consulting Engineer, Moorehead, Minn.

Ian M. Sutherland, Engineer Draftsman, Water Board, 110 Spencer Street, Melbourne, Australia.

Corporate Members

Federal Light & Traction Company, 60 Broadway, New York, N. Y.

Hot Springs Water Company, Hot Springs, Ark.

Sea Breeze & Vicinity Water Commission, Charles S. Evershed, Treasurer, R. F. D. 5, Rochester, N. Y.

Southern Illinois Light & Power Company, 902–10 Central National Bank Building, St. Louis, Mo.

Associate Member

The Mathieson Alkali Works, Incorporated, 25 West 43d Street, New York, N. Y.

DEATHS

Frank L. Fuller, Wellesley Hills, Mass., elected member July 10, 1906, died January 30, 1920.

Robert A. Jackson, Norristown, Pa., elected member June 24, 1893, died March 2, 1920.

Daniel B. McCarthy, New York, N. Y., elected member June 27, 1905, died March 6, 1920.